Water Quality Improvement Plan
for

Middle Fork South Beaver Creek

Grundy County, Iowa

Total Maximum Daily Load
for Sediment and Phosphorus

Iowa Department of Natural Resources
Watershed Improvement Section
2007

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General Report Summary

What is the purpose of this report?

This report serves dual purposes. First, it is a resource for guiding locally-driven water quality improvements in the Beaver Creek and Cedar River basins. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) report for all federally impaired waterbodies. Middle Fork South Beaver Creek is an important headwater to the Cedar River, and as an impaired watershed it is eligible for increased financial assistance. This document is meant to help guide watershed improvement activities to remove Middle Fork South Beaver Creek from the federal 303(d) List.

What's wrong with Middle Fork South Beaver Creek?

Middle Fork South Beaver Creek is not supporting the amount and diversity of aquatic life that it should. Over the years, too much sediment has been delivered to the stream causing a loss in habitat for bottom-dwelling invertebrates. Also, high nutrient concentrations in the water lead to excessive plant growth and respiration, causing extreme dissolved oxygen swings and nighttime lows.

What is causing the problem?

Large areas of bare soil that have little or no vegetative cover during the rainy season are susceptible to the processes of sheet and rill erosion. During heavy rains and snowmelt events, bare areas that are close to the stream or which develop concentrated surface runoff can deliver large sediment loads to the stream.

The high nutrient concentrations stem from a number of sources. Dissolved and sediment-attached phosphorus from nonpoint sources, carried to the stream by surface runoff and tile flow, are estimated to make up 77% of the annual loading. Point source pollution is estimated to contribute 16% of the annual phosphorus loading. Failing septic tanks, cattle in the streams, and natural loading by atmospheric deposition make up a minor portion of the total annual load (7%).

What can be done to improve Middle Fork South Beaver Creek?

To improve the health of this stream and of downstream rivers, sediment and phosphorus delivery from nonpoint sources need to be reduced significantly. This can be done by focusing on areas in the watershed that aren't currently using any soil conservation and/or nutrient management practices. Stream buffers, comprehensive nutrient management plans, cover crops, and controlled drainage are all potential measures for reducing sediment and phosphorus loading in the stream. There are many financial and technical assistance grants available to assist landowners who are interested.

Water quality monitoring is also a critical component in any watershed project. Monitoring helps identify dominant sources, characterize long term trends, and evaluate the impacts of watershed improvements. Currently, there is no monitoring being done in the stream; therefore, an active and devoted network of volunteer monitoring is strongly recommended.

Who is responsible for a cleaner Middle Fork South Beaver Creek?

Everyone who lives and works in the watershed has a role in improving and maintaining Middle Fork South Beaver Creek. With all or nearly all of the 27,000 watershed acres in private ownership, government agencies can provide financial and technical assistance to landowners who are willing to adopt land use changes on a voluntary basis. Individual citizens who are interested can contact their local soil and water conservation district or the Iowa DNR Watershed Improvement Section for information on how they can make a difference.

For more information:

Iowa DNR Watershed
Improvement Section
502 E. 9th Street
Des Moines, IA 50319
515-281-4791

Grundy Soil and Water
Conservation District
805 West 4th Street, Ste. 2
Grundy Center, IA 50638
319-824-3634

Hardin Soil and Water
Conservation District
840 Brooks Road
Iowa Falls, IA 50126
641-648-3463

Required Elements of the TMDL

Name and geographic location of the impaired or threatened waterbody for which the TMDL is being established:	Middle Fork South Beaver Creek, from mouth in Grundy Co. (N ½, S28, T89N, R17W) to headwaters in Hardin County (NW1/4, S15, T89N, R19W).
Impaired waterbody segment identification number:	IA 02-CED-0432
Current surface water classification and use designation (dependent upon final use attainability analysis):	Primary contact recreation (A) and warmwater aquatic life (B)
Impaired use:	Warmwater aquatic life (Class B)
TMDL priority level:	Consent Decree waterbody
Identification of the pollutants and applicable water quality standards:	Excessive sediment and phosphorus have caused a chronic biological impairment in the stream, violating warmwater aquatic life uses (Class B). Iowa's water quality standards do not have numeric criteria for either sediment or phosphorus.
Quantification of the pollutant loads that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	For sediment, the Phase 1 load capacity is 2,580 tons/year. This equates to a daily average of 7.1 tons/day, with a daily maximum of 487 tons. For total phosphorus, the Phase 1 load capacity is 17,921 lbs/year. This equates to a daily average of 49.1 lbs/day, with a daily maximum of 142 lbs.
Quantification of the amount or degree by which the current pollutant loads in the waterbody, including the pollutants from upstream sources that are being accounted for as background loading, deviate from the pollutant loads needed to attain and maintain water quality standards:	Existing sediment delivery is estimated to be 6,291 tons per year on average, with estimated daily loads as high as 1,188 tons/day. A 59% reduction in annual sediment delivery is called for in Phase 1. Existing total phosphorus loads are estimated to be 29,868 lbs/year on

	average, with daily loads as high as 237 lbs/day measured in the stream. Phase 1 calls for a 40% reduction in total phosphorus loading.
Identification of pollution source categories:	Nonpoint sources of sediment include sheet and rill erosion and minor bank erosion. Nonpoint sources of phosphorus consist mainly of surface runoff which carries both dissolved and sediment-attached phosphorus, tile flow, and minor contributions from cattle in streams, atmospheric deposition, and failing septics. There is one point source discharger in the watershed: the City of Ackley operates a three-cell aerated lagoon which discharges continuously to the creek (NPDES #4201001). There are currently no NPDES-permitted animal feeding operations.
Wasteload allocations for pollutants from point sources:	The sediment wasteload allocation is set at the existing level of 146 tons/year, or 0.4 tons/day. The total phosphorus wasteload allocation is 4,855 lbs/year. This equates to a daily average of 13.3 lbs/day, with a daily maximum of 32.9 lbs. NPDES monitoring requirements for total phosphorus are to be implemented in Phase 1 to assist with setting an appropriate wasteload allocation in Phase 2.
Load allocations for pollutants from nonpoint sources:	The sediment load allocation for nonpoint sources is 2,434 tons/year. This equates to a daily average of 6.7 tons/day with a daily maximum of 487 tons. The total phosphorus load allocation for nonpoint sources is 13,066 lbs/year. This equates to a daily average of 35.8

	lbs/day with a daily maximum of 109.1 lbs.
A margin of safety:	A margin of safety is implicit by employing a phased/adaptive TMDL strategy and by conservative assumptions made in load estimates.
Consideration of seasonal variation:	Phase 1 sediment and phosphorus targets are expressed as annual loadings to reflect the chronic nature of the impairment, with the phosphorus target being designed to allow the stream to meet dissolved oxygen standards at critical low flow conditions.
Reasonable assurance that load allocations and wasteload allocations will be met:	Wasteload allocations will be implemented under the NPDES permitting program for point source dischargers. Load allocations can be achieved voluntarily via watershed/water quality assistance grants provided by state government agencies and technical support from local Soil and Water Conservation Districts.
Allowance for reasonably foreseeable increases in pollutant loads:	Nearly all land available for intensive agriculture is currently under such use, and human & livestock populations appear stable. Therefore, no allowance for an increase in pollutant loads was given.
Implementation plan:	Although not required by the Clean Water Act, a general Implementation Plan is included in Chapter 5 of this report to assist watershed managers in removing this stream from the 303(d) List.

1. Introduction

The Federal Clean Water Act of 1972 requires that all states develop lists of impaired waters which are not meeting designated water quality standards. This list is commonly called the 303(d) list. In addition, a Total Maximum Daily Load (TMDL) report must also be developed for each impaired waterbody that appears on the list.

A TMDL is a calculation of the maximum amount of pollution a waterbody can tolerate without exceeding its water quality standards. The report must allocate portions of the total maximum daily load to nonpoint and point sources (called the load allocation and wasteload allocation, respectively), allow for a margin of safety, and account for seasonal variations in hydrology and pollutant loading. Usually, TMDLs are expressed in units of mass per day.

This document represents Phase 1 of the TMDL report for Middle Fork South Beaver Creek, located in Grundy County, Iowa. This stream was first listed as impaired in 1998, following several fish kills near Ackley, Iowa. Although one source of the fish kills is now absent from the watershed, an investigation into the stream's biotic integrity has revealed that a chronic impairment in the benthic macroinvertebrate community still exists. Over the years, chronic sedimentation/siltation of the streambed and excessive plant nutrients in the stream have led to low biological diversity and limited aquatic life seen in the stream today.

Phasing TMDLs is an adaptive approach to managing water quality that becomes necessary when the origin, nature, or sources of the impairment are not fully understood or easily monitored. In Phase 1, specific and quantifiable targets are set based on the best available information. Implementation efforts will focus on voluntary adoption of nonpoint source conservation practices and the collection of additional monitoring data. Phase 2 will be initiated once conservation practices are deemed to have improved water quality in the stream and a sufficient body of data exists to more accurately define the stream's pollutant loading capacity. This may include revising or adjusting targets set forth in Phase 1.

This TMDL report is most functional as a resource that can be used to guide on-the-ground, grassroots projects that are coordinated and targeted to address activities in the entire watershed. Neither this report nor government action alone can explicitly fix the impairment in the stream; for that it will take citizen activism and involvement. The water quality in Middle Fork South Beaver Creek is a reflection of the surrounding land which drains to it and how it is managed. As such, local landowners, tenants, and businesses have the most power in deciding how good its water quality is.

2. Description and History of Middle Fork South Beaver Creek

Middle Fork South Beaver Creek is a small tributary which begins in northeast Hardin County and flows in a general southeasterly direction into South Beaver Creek in Grundy County. Water and materials in Middle Fork South Beaver Creek eventually reach the Cedar, Iowa, and Mississippi Rivers.

2.1. Middle Fork South Beaver Creek

Hydrology. Middle Fork South Beaver Creek flows approximately 17.8 miles from its headwaters, near the city of Ackley, to its mouth at the confluence with South Beaver Creek in Section 28 of T89N, R17W (Pleasant Valley Township). In addition to the 17.8-mile main branch, the North Fork of South Beaver Creek and multiple unnamed tributaries also feed the stream and total approximately 22.8 miles in length. Many of the tributaries and stream segments are artificial drainage ditches and/or straightened channels designed to drain the landscape more efficiently for agricultural production. Tile drainage is a common practice in the Middle Fork South Beaver Creek watershed, resulting in improved agricultural field conditions but an altered hydrologic system.

Streamflow is not regularly monitored in Middle Fork South Beaver Creek. However, the United States Geologic Survey (USGS) maintains a year-round discharge gaging station approximately 19 miles downstream on Beaver Creek in Butler County. Data from this gage was normalized by drainage area and used to estimate daily streamflow in Middle Fork South Beaver Creek, which were verified by flow measurements taken during irregular samplings in 2001 and 2003 (Appendix D). The period of record for these flows is from October 1, 1945 to December 26, 2006 at a daily frequency.

The synthetic flow record estimated at the outlet of Middle Fork South Beaver Creek has daily discharges ranging from less than one cubic feet per second (cfs) (on 9/30/1989) to 1,992 cfs (on 6/13/1947). The mean daily flow rate is 27 cfs, and the median daily flow rate is 11 cfs. Figure 1 shows a flow duration curve for Middle Fork South Beaver Creek at various percentiles. Values on the horizontal axis represent the percent of days where flow was equal to or greater than the corresponding daily discharge value on the vertical axis.

One aspect of the stream hydrology that cannot be ignored is the contribution from sanitary wastewater. The City of Ackley discharges continuously from a three-cell aerated lagoon, at times accounting for up to 65% of the streamflow in Middle Fork South Beaver Creek. On average, wastewater effluent accounts for 18% of the daily flows in the stream.

Morphology & substrate. Along its length, Middle Fork South Beaver Creek varies greatly between straight/channelized to strongly meandering. The average sinuosity among reaches of equal elevation drop (calculated as total meandering length of reach/straight line length of reach) is 1.5, which is relatively low. Low sinuosity/meandering imply a higher degree of channel modification and disruption of natural ecosystem processes. Some reaches of the stream are deeply incised, indicating past disturbance to the channel and reduced floodplain connectivity. Currently, Middle Fork South Beaver Creek has a relatively stable channel with little obvious degradation occurring. The dominant substrate in the channel is sand and gravel, but much of the streambed is silted in.

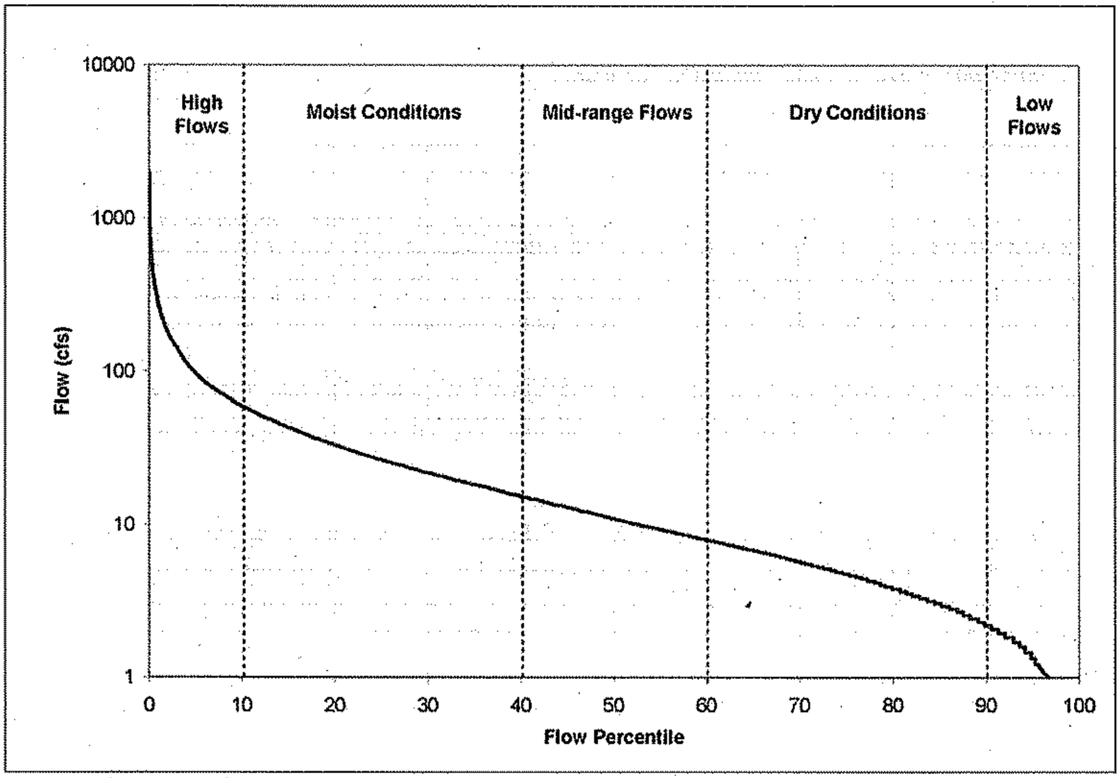

Figure 1. Daily flow exceedance chart for Middle Fork South Beaver Creek.

2.2. The Middle Fork South Beaver Creek Watershed

The amount of land surface area draining to Middle Fork South Beaver Creek is approximately 27,081 acres, or 42.3 square miles. This includes one incorporated city (Ackley, population 1,809) and approximately 363 rural housing units (U.S. Census Bureau, 2000). Figure 2 provides a map of the watershed and its location in Iowa.

Land use. Land use in the Middle Fork South Beaver Creek watershed is highly agricultural. The most common agronomic crops grown in the watershed are corn and soybeans, but some hay and small grains are also raised. Hogs and beef cattle are the primary livestock operations, with several confinement feeding operations and open feedlots present in the watershed. However, none of the animal feeding operations present in the watershed require NPDES permits. The most prevalent conservation practices in the watershed include terraces, grass waterways, filter strips/buffers, and Conservation Reserve Program (CRP) land enrollments.

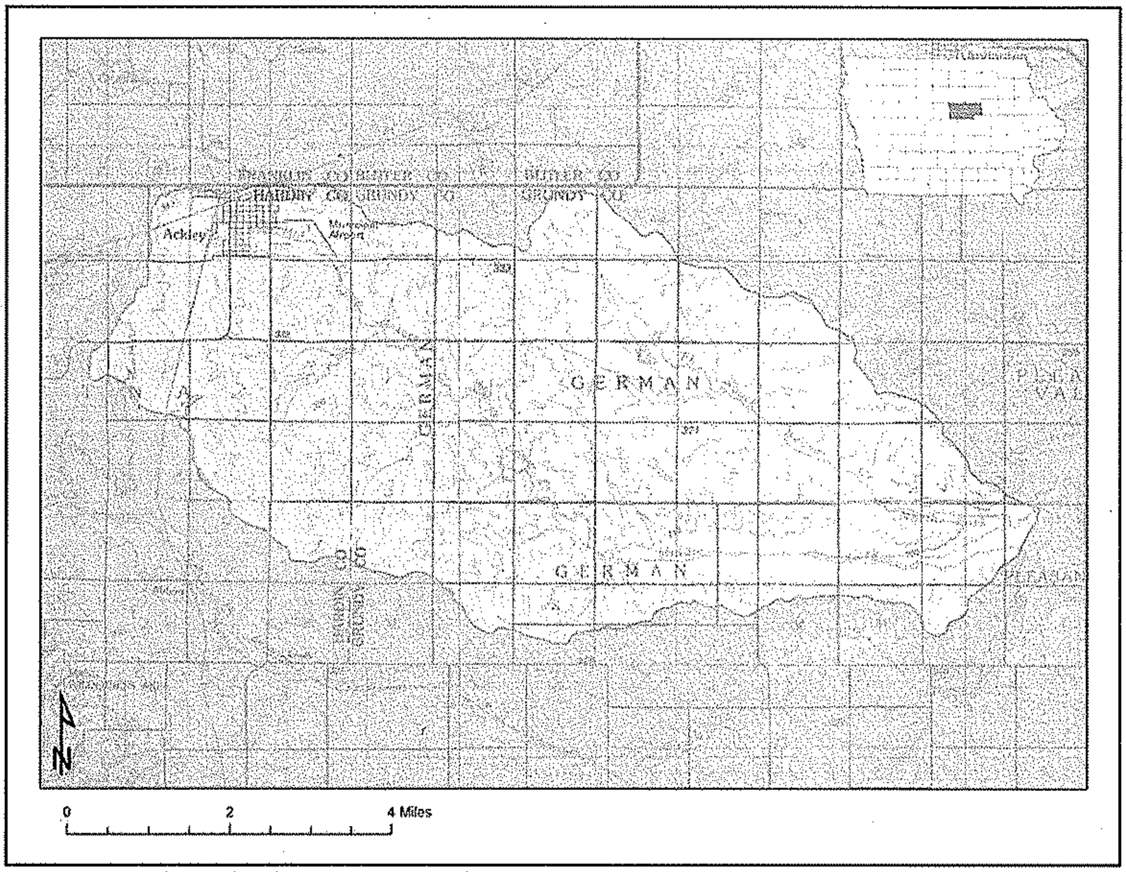

Figure 2. The Middle Fork South Beaver Creek watershed.

A field-level assessment of land use in the watershed was performed in 2003 for the purpose of TMDL development. Figure 3 shows the results of this assessment, and Table 1 gives the landcover distribution for the entire watershed.

Soils, climate, and topography. The Middle Fork South Beaver Creek watershed is located on the Iowan Surface Ecoregion (Level IV) (Chapman et al., 2001). This landform is broadly characterized by long, gentle slopes and mature drainage patterns. Rivers in this region have relatively low gradients, as there is little topographic relief. Geologic materials include limestone bedrock, glacial till, and loess (Prior, 1991).

The watershed is nearly level to strongly sloping (0-18%), consisting of prairie-derived soils developed from loess, loess over silty and loamy material, and alluvium. The most common soil types in the uplands are Dinsdale, Tama, and Klinger. Colo, Wiota, and Nevin are the dominant soil series in stream valleys & floodplains.

Climate is typical of the upper Midwest, with cold winters and warm summers. Average annual precipitation for the period of record (1951-2005) is 32.3 inches (IEM, 2007). Most of this precipitation (23-24 inches) falls between the months of April and September (Andrews, 1977 and Voy, 1985). The maximum yearly precipitation

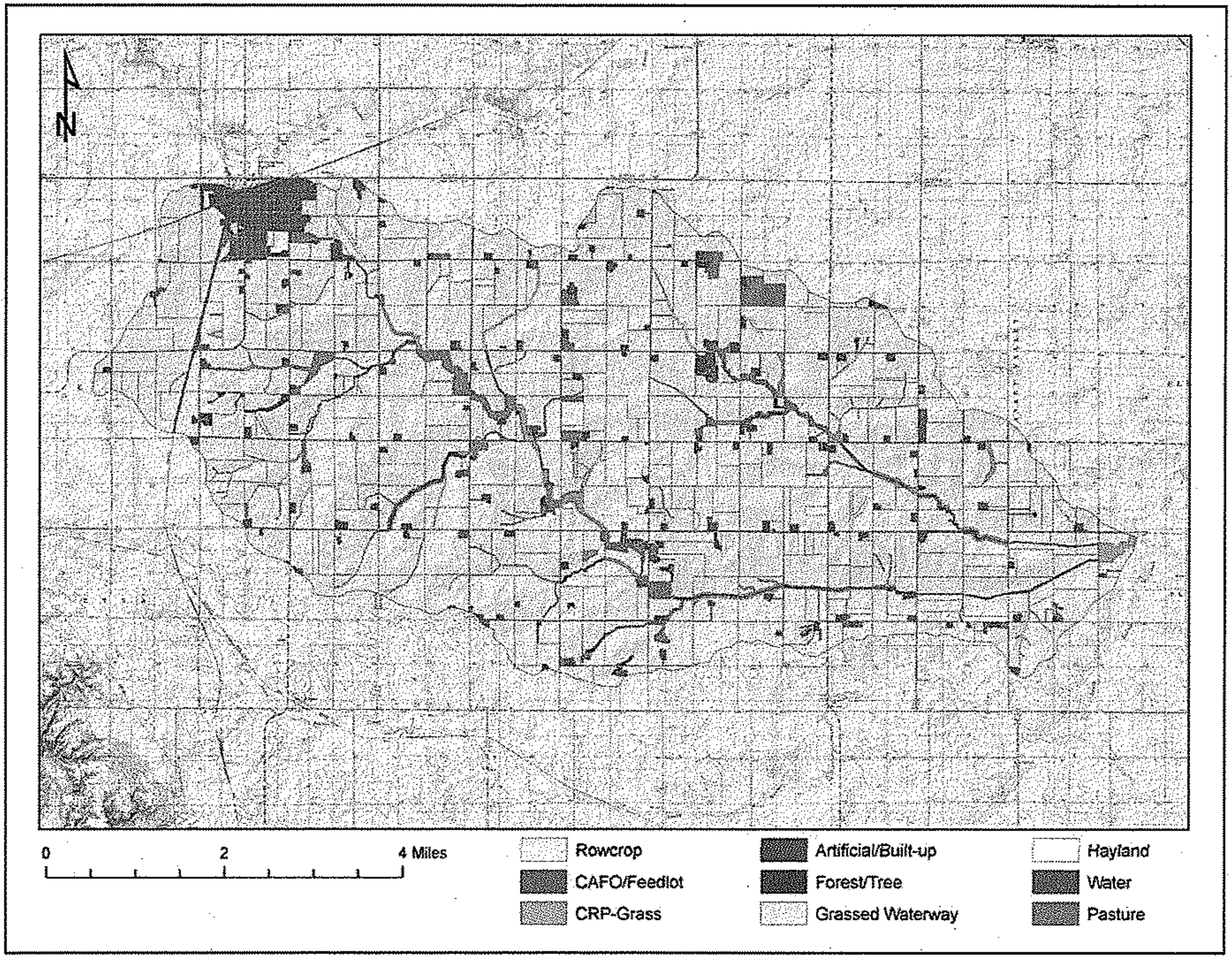

Figure 3. Landcover map of Middle Fork South Beaver Creek watershed (2003 windshield survey data).

occurred in 1993, with 53.3 inches. The minimum yearly precipitation, 17.3 inches, occurred in 1984.

Table 1. Watershed landcover distribution.

Landcover	Acres	Percent of total
Row crops	23,768	88%
Artificial/Built-up	1,375	5%
Pasture	657	2%
Forest/Tree	396	1%
Hayland	354	1%
CRP-Grass	308	1%
Grassed Waterway	154	1%
Water	37	0.1%
CAFO/Feedlot	31	0.1%
Total:	**27,081**	**100%**

2.3. Biological Impairment

Problem Statement. Middle Fork South Beaver Creek is not fully supporting its aquatic life uses. The first indication of this was a series of four fish kills that occurred in the stream between 1991 and 1997. These prompted the Iowa DNR to include the Middle Fork of South Beaver on the 1998 Impaired Waters List (303(d) List). Following this, the Iowa DNR performed biological sampling of the benthic and fish communities in 2001 at two locations (Figure E1 in Appendix E) and collected water chemistry data in both 2001 and 2003. The results showed that while the fish community was in fair to good condition, benthic macroinvertebrate scores were in the fair to poor range (see next section, *Bioassessments and Index of Biotic Integrity*). Furthermore, continuous autosampler data showed numerous violations of the state's dissolved oxygen standard during nighttime periods throughout the sampling period (Figure 4).

The fish kills that occurred in the stream during the 1990's were considered episodic events which resulted in acute impacts to the stream biological community. Table 2 summarizes information about these events. The industrial cannery, which contributed to the two most severe fish kills in the stream (1991 and 1997), no longer exists in the watershed; however, the poor condition of the stream's benthic macroinvertebrate community and the obvious violations of the state's dissolved oxygen standards during nighttime hours prompted the U.S. Environmental Protection Agency (EPA) to issue a "non-supporting" assessment of the stream's aquatic life uses for the 2004 305(b) Assessment.

Bioassessments and Index of Biologic Integrity. To assess harmful, chronic impacts to biological communities in aquatic ecosystems, the Iowa DNR uses an index-based scoring approach originally conceived by Karr (1981) and described in detail by Wilton (2004). The Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and Fish Index of Biotic Integrity (FIBI) approach uses multiple metrics to provide a broad assessment of the biological condition of the stream. The number and richness of biological species that are present in the stream, along with assessments of the physical habitat quality adequately characterize the effects of chronic stressors to the ecosystem over time. The causes are later determined using a process known as a Stressor Identification.

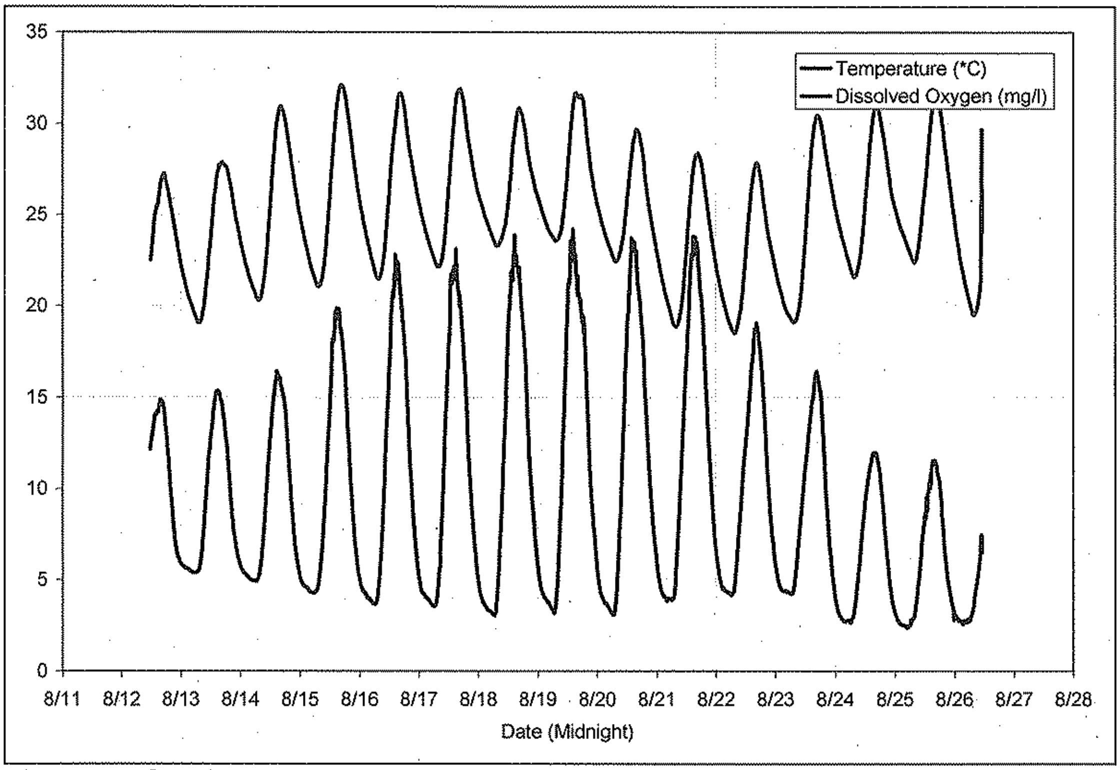

Figure 4. Continuous autosampler data collected at Site 45 in 2003.

Table 2. History of fish kills since 1991.

Year	Cause of Kill	# Fish Killed	Type of Fish Killed
9/7/91	Stuck irrigator led to overapplication of organic wastewater from cannery.	5,957	Various minnows, Sunfish, and Catfish
8/17/94	Surface runoff from silage pile washed high oxygen-demanding materials into stream.	Not Available	Not Available
8/10/95	Surface runoff from silage pile washed high oxygen-demanding materials into stream.	319	White Suckers, Chubs, Bluegills
9/12/97	Industrial discharge of organic materials from cannery.	667	Minnows, Chubs, Stonerollers, Suckers, Sunfish

In Middle Fork South Beaver Creek, scores of biotic integrity were better at the downstream site than at the upstream site, as shown in Figure 5. Reference scores (represented by horizontal bars) are determined as the 25th percentile values of all compiled reference stream scores in the Iowan Surface ecoregion. Reference streams are relatively unaltered, healthy aquatic ecosystems that are used as benchmarks for comparing bioassessment scores and for 305(b) and 303(d) purposes.

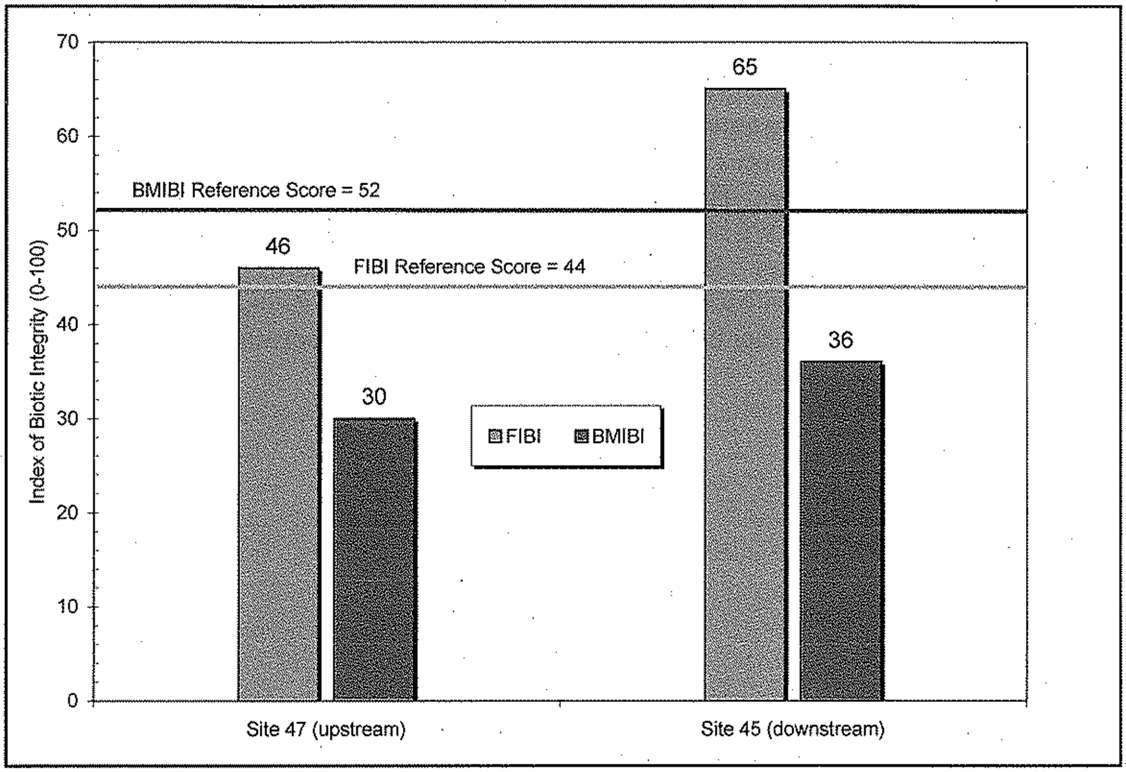

Figure 5. Bioassessment scores in Middle Fork South Beaver Creek (2001).

Fish scores (FIBI) in Middle Fork South Beaver Creek are adequate at both monitoring sites; however, benthic macroinvertebrate scores are sub-standard. Benthic macroinvertebrates make up a critical component in the aquatic ecosystem, providing a food base for larger aquatic life as well as serving as a dependable indicator of water quality and chronic stream health. For the stream to reach a state where it is fully supporting its aquatic life uses, both BMIBI and FIBI scores should meet or exceed the 25^{th} percentile scores for reference streams, in addition to other numeric standards for Class B streams.

Stressor Identification. A Stressor Identification (SI) was performed to determine the specific causes of impairment to the benthic macroinvertebrate community in Middle Fork South Beaver Creek (IDNR, 2005). The SI is a scientifically rigorous procedure based on federal guidelines (USEPA, 2000) in which all potential stressors to the aquatic ecosystem are considered in determining the cause(s) of biological impairment. In the case of the Middle Fork South Beaver Creek, potential stressors that were eliminated during the screening process included suspended solids/turbidity, toxins, ammonia, pH, dewatering, channelization, loss of riparian vegetation, and flow alteration. The primary causes of the biological impairment were determined to be excessive silt/sediment, excessive nutrients (nitrogen and phosphorus), excessive algal growth, and low levels/ extreme fluctuations in dissolved oxygen.

Of these stressors, several are interrelated (as the SI document points out). The extreme fluctuations and low nighttime levels of dissolved oxygen in the stream are the result of excessive plant/algal growth in the stream during late summer low-flow periods. This is in turn related to excessive nutrient loading, in combination with the physical conditions. As the primary limiting nutrient in freshwater aquatic ecosystems, phosphorus plays the most critical role in limiting aquatic plant growth. Chapter 4 and Appendix D discuss the correlation between phosphorus and algae in the stream, while the relationship between nitrogen and algae is weaker. Therefore, for the purposes of TMDL development, the specific causes of the stream's biological impairment can be effectively reduced to two primary pollutants: excessive silt/sediment and excessive phosphorus loading. More detailed information on how each of these pollutants is affecting the aquatic life in Middle Fork South Beaver can be found in Chapters 3, 4, and Appendix D of this report.

3. Total Maximum Daily Load (TMDL) for Sediment

A Total Maximum Daily Load (TMDL) is required for Middle Fork South Beaver Creek by the Federal Clean Water Act. This chapter will quantify the maximum amount of sediment that Middle Fork South Beaver Creek can tolerate without violating its designated uses.

3.1. Problem Identification

As stated in the previous section, the Stressor Identification (SI) that was performed on Middle Fork South Beaver Creek found that one of the specific causes of impairment to the benthic macroinvertebrate community has been excessive siltation/sedimentation of the streambed over time (IDNR, 2005):

> *"Excessive silt and sediment deposition in Middle Fork South Beaver Creek have led to a reduction in the BMIBI scores. Siltation and sedimentation have caused a loss of riffle habitat, which limits the growth of benthic macroinvertebrates. Siltation and sedimentation were determined to be a problem based on habitat data collected by the DNR/UHL biological assessment team (Table 4; Appendix I). The percent silt is much greater than the average and median for the ecoregion reference locations. The high percent embeddedness of the riffles at site 45 is also indicative of a siltation problem. Although the percent total fines is lower at site 47 than the reference condition, the accumulation of muck and detritus is quite extensive. The lack of riffle and run limits the diversity of habitats available to aquatic organisms and thereby limits the diversity of the organisms themselves. In addition, the field team noted that the standard habitat plates were heavily silted at both sites...The evidence is strong enough to justify action to reduce siltation and sedimentation in Middle Fork South Beaver Creek. Such action will have a positive effect on the biological community of the creek."*

Applicable water quality standards. As a perennial waterbody, Middle Fork South Beaver Creek is currently protected for contact recreation and warmwater aquatic life uses (Classes A and B, respectively), as well as being protected by the antidegradation policy and general/narrative water quality criteria as defined in Iowa's Water Quality Standards (IAC, 2006). The stream's final designated uses are dependent upon a field-based use attainability analysis (UAA).

The State of Iowa does not have a numeric standard for sediment/siltation in lakes or rivers. Therefore, information on the degree of streambed siltation (collected in the field during habitat bioassessments in 2001) is used to set targets for sediment loading reductions. These targets are discussed in the following sections.

Data sources. Data used for the Stressor Identification included biological sampling data collected by Iowa DNR staff in 2001, water chemistry sampling by University Hygienic Lab (UHL) in both 2001 and 2003 (including autosampler data), and data from the legacy STORET system collected at two locations on September 22, 1975.

Data on streambed siltation was collected in 2001 at two sites by Iowa DNR and University Hygienic Lab (UHL) staff. Similar data collected at multiple sites throughout the Iowan Surface Ecoregion provided reference condition scores for siltation. These data are shown in Table 3, and are discussed in further detail in Section 3.2.

Table 3. Streambed siltation indicators in Middle Fork South Beaver Creek.

Parameter	Site 45 (downstream)	Site 47 (upstream)	Region 47c Reference (mean, median)
% total fines	76	46	59, 54
% silt	57	35	15, 9
% detritus/muck	*	32	*
% embeddedness	41-60	NA	**
% riffle	5	0	8.7, 8.5
% run	11	0	60, 61
% pool	84	100	32, 25

NA – no riffles to measure embeddedness; * – not measured;
** – reference measured as a range, not a numerical value

Interpreting Middle Fork South Beaver data. In Table 3, the percent silt indicates the degree of siltation/sedimentation in the stream (35% at the upstream site, 57% at the downstream site). These values are estimated by point samples taken along cross-sectional transects throughout the stream reach (ten transects, five points per transect). They represent the fraction of samples with "silt" identified as the dominant substrate at that point. Typical siltation rates for healthy streams in this ecoregion are much lower, with 15% being the mean value and 9% the median for Iowan Surface reference sites.

3.2. TMDL Target

General description of the pollutant. Silt and sediment are naturally transported by streams and rivers. However, excessive sediment loads delivered from upland watershed sources via sheet, rill, & gully erosion can result in sediment deposition (siltation) of streams and lakes causing a loss of aquatic habitat and reduced channel transport capacity. Excessive turbidity and siltation can be detrimental for sight-feeding fish, benthic-dwelling organisms, and basic aquatic life functions. Alterations to a stream's natural hydrologic regime (such as channelization and/or artificial drainage) can cause an imbalance in the natural discharge-sediment load equilibrium of the stream and lead to bed and bank degradation, also contributing to excessive siltation/sedimentation (Lane, 1955).

Selection of environmental conditions. Critical or seasonal environmental conditions do not apply. Siltation/sedimentation pose long-term, chronic threats for aquatic life and as such do not warrant consideration for acute seasonal impacts.

Waterbody pollutant loading capacity (TMDL). The Phase 1 goal for Middle Fork South Beaver Creek is to reduce the average siltation/sedimentation rate of the streambed from its current level ($\bar{x}$ = 46% silt between two sites) to that of the 75th percentile of data for reference streams in the Iowan Surface Ecoregion (19% silt). To achieve this, in-stream siltation/sedimentation of the channel would need to be reduced by 59% from current levels.

Assuming the relationship between external sediment delivery to the stream and the siltation/sedimentation rate of the streambed will remain proportional and constant over time, the external sediment loading reduction needed to achieve the Phase 1 TMDL target is also 59%. The load capacity for sediment, then, is 2,580 tons/year, or 7.1 tons/day on average. The maximum daily load for sediment is 487 tons, determined using a statistical dataset derived from estimates of annual sediment loading and daily rainfall data. Section 3.3 and Appendix D provide details on the methods and models used to estimate current sediment delivery in the watershed.

Decision criteria for water quality standards attainment. The decision criteria for water quality standards attainment in Middle Fork South Beaver Creek are based on meeting biological conditions typical of healthy reference streams for this ecoregion. This would requires achieving and maintaining a BMIBI score of 52 and a FIBI score of 44. Reference scores are subject to change as future data is collected and reference conditions are recalibrated and adjusted.

3.3. Pollution Source Assessment

Existing load. Existing sediment loads delivered to Middle Fork South Beaver Creek are not regularly monitored, therefore long-term approximations of the annual sediment loads were estimated based on the Revised Universal Soil Loss Equation (RUSLE) and a cursory assessment of gullies and eroding stream banks present in the watershed. Figure 6 shows the estimated annual sediment loading to the creek from 1951 to 2005, which vary around the long term annual average of 6,145 tons/year depending on rainfall. On a daily time step, existing loads vary between 0 and 1,188 tons/day, with a mean of 16.8 tons/day. Maximum daily loads from point sources were calculated based on TSS values and flow. This results in an existing maximum daily load of 0.4 tons, and an annual sediment load of 146 tons. This results in a total existing sediment load of 6,291 tons/year.

Departure from load capacity. The Phase 1 target for sediment loading to Middle Fork South Beaver Creek is 6.9 tons per day or 2,580 tons per year. Existing daily loads of sediment in the stream are 17.2 tons/day or 6,291 tons/year on average. A 59% reduction in current sediment delivery to the stream is needed to achieve the Phase 1 TMDL target.

Identification of pollutant sources. Sediment is delivered to the stream during rain events from nonpoint sources throughout the watershed. Sheet and rill erosion occurring in agricultural fields represents the overwhelming dominant source of sediment in the Middle Fork South Beaver Creek watershed (99%). Figure 7 provides a map of the

RUSLE-derived sheet and rill erosion sources. Several additional maps that should be useful for helping watershed managers prioritize soil conservation needs are shown in Chapter 5.

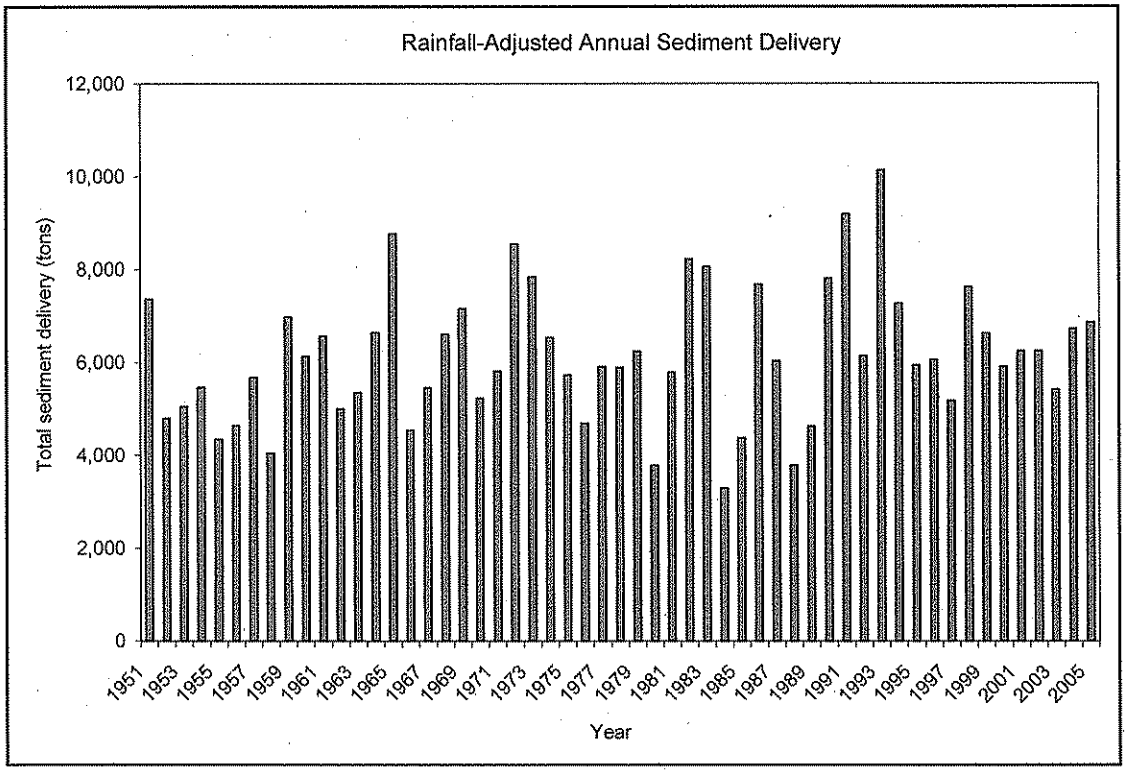

Figure 6. Estimated annual sediment delivery to Middle Fork South Beaver Creek.

Allowance for increases in pollutant loads. Most of the land area in the Middle Fork South Beaver Creek watershed available for row crop farming is currently under such land use practice. Stream channels in the watershed appear to be mostly stable at this time and are not expected to degrade or widen excessively in the coming years. Therefore, no allowance for increased sediment loads was given in the TMDL.

3.4. Pollutant Allocation

Wasteload allocation. A wasteload allocation represents the fraction of the TMDL apportioned to point sources in the watershed. The only point source discharger in the Middle Fork South Beaver Creek watershed is the City of Ackley wastewater treatment plant. An existing maximum daily load of 0.4 tons has been calculated for the City of Ackley WWTP. This is not a significant contributor of siltation/sedimentation in the stream. Therefore, the wasteload allocation for sediment will be set at existing levels of 0.4 tons/day.

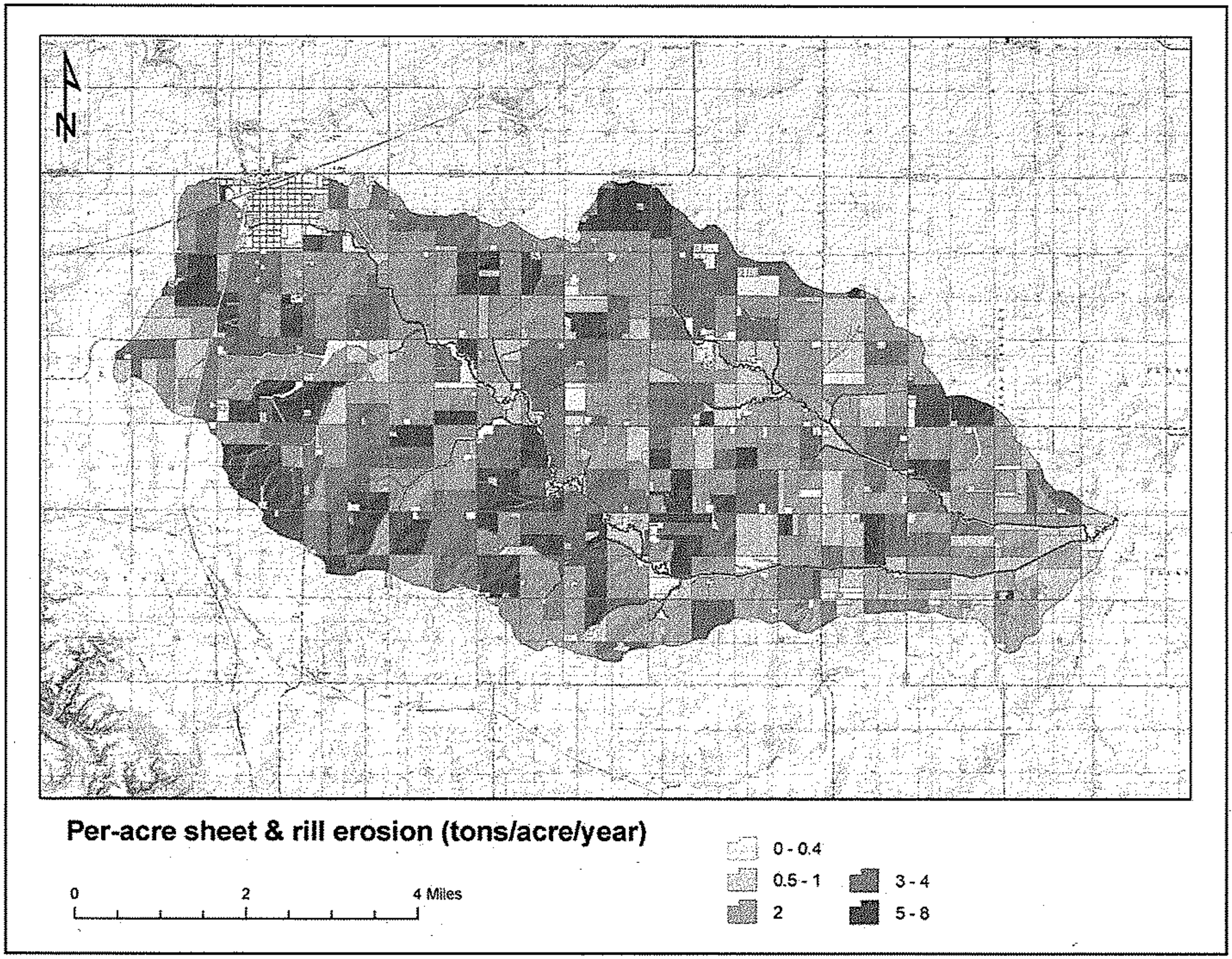

Figure 7. Sheet and rill erosion rates based on 2003 landcover data (averaged by field boundaries).

Load allocation. The load allocation represents the fraction of the TMDL apportioned to nonpoint sources in the watershed. In Middle Fork South Beaver Creek, 98% of the existing sediment loads originate from nonpoint sources; therefore, the load allocation is equivalent to the Phase 1 target of 2,580 tons per year minus the wasteload allocation of 146 tons/year, or 2,434 tons/year (6.7 tons/day on average (487 tons daily maximum).

Margin of safety. To account for uncertainties in data or modeling, a margin of safety is a requirement of all TMDLs. For this TMDL, the use of a phased TMDL approach provides an implicit margin of safety to account for uncertainties in nonpoint source sediment delivery. Furthermore, estimates of long term sediment loading were based on the absence of existing conservation practices which provides an additional implicit margin of safety.

3.5. TMDL Summary

The following equation represents the Phase 1 sediment Total Maximum Daily Load (TMDL) and its components for Middle Fork South Beaver Creek:

TMDL = Load Allocation (nonpoint sources and background) + Wasteload Allocation (point sources) + Margin of Safety (either explicit or implicit)

Sediment TMDL (487 tons) = Load Allocation (487 tons) + Wasteload Allocation (0.4 tons) + Implicit Margin of Safety

Expressed annually,

Sediment $\text{TMDL}_{\text{Annual}}$ (2,580 tons/yr) = Load $\text{Allocation}_{\text{Annual}}$ (2,434 tons/yr) + Wasteload $\text{Allocation}_{\text{Annual}}$ (146 tons/yr) + Implicit Margin of $\text{Safety}_{\text{Annual}}$

Expressed as daily average,

Sediment TMDL (7.1 tons/day) = Load Allocation (6.7 tons/day) + Wasteload Allocation (0.4) + Implicit Margin of Safety

4. Total Maximum Daily Load (TMDL) for Total Phosphorus

A Total Maximum Daily Load (TMDL) is required for Middle Fork South Beaver Creek by the Federal Clean Water Act. This chapter will quantify the maximum amount of total phosphorus that Middle Fork South Beaver Creek can tolerate without violating the state's water quality standards.

4.1. Problem Identification

As stated in Section 2.2, the Stressor Identification (SI) that was performed on Middle Fork South Beaver Creek found that one of the specific causes of impairment to the benthic macroinvertebrate community has been excessive nutrient loading (IDNR, 2005):

> *"Excess nutrients, both nitrogen and phosphorus, in Middle Fork South Beaver Creek have led to reduced BMIBI scores. Nutrients in the stream allow for excessive algal growth which can cause pronounced daily swings in dissolved oxygen and nightly dissolved oxygen sags. In Middle Fork South Beaver Creek, these sags send dissolved oxygen levels below the 4 mg/l standard (IAC 2004) regularly during low flow periods. These levels of oxygen could be causing stress in the invertebrate community. Algal growth in the benthos can also limit the availability of habitat for benthic macroinvertebrates.*
>
> *... We are confident that the data are sufficient and accurate, allowing us to conclude that high nutrient levels in Middle Fork South Beaver Creek contribute significantly to the problems of the biological community. We believe that there is strong enough evidence to justify action to reduce phosphorus and/or nitrogen levels in Middle Fork South Beaver Creek and that this action will have a positive impact on the biological community in the creek."*

As the previous quote suggests, excessive nutrients in the stream are indirectly creating dissolved oxygen problems by promoting too much algae and macrophyte growth. Figure 4 in Chapter 2 showed how dissolved oxygen levels in the stream fluctuate drastically between daytime and nighttime hours due to abundant plant photosynthesis and respiration. Such wide swings in daily dissolved oxygen are harmful to aquatic organisms, as are the absolute lows which occur at night during the dark hours of peak respiration.

Phosphorus is the primary limiting nutrient for plant growth in Middle Fork South Beaver Creek. Figure 8 shows the correlation between plant-available phosphorus in the water column and chlorophyll-a concentrations in stream periphyton (bottom algae) (correlation coefficient = 0.88, $p = .049$). Conversely, the relationships between nitrogen and algae are weaker, as Figure D5 in Appendix D shows. Total nitrogen (TN) to total phosphorus (TP) ratios at the downstream monitoring site are 97:1 on average, and are consistently greater than 20:1. Typically, a TN:TP ratio greater than 10:1 implies that phosphorus is the primary limiting nutrient for plant growth (Sharpley et al., 1994). Therefore, nitrogen is not considered to be as important in controlling aquatic plant life in the stream, and will not receive a TMDL for Phase 1; if information collected for Phase 2 of the TMDL suggests that nitrogen is contributing to the impairment, it will be considered then.

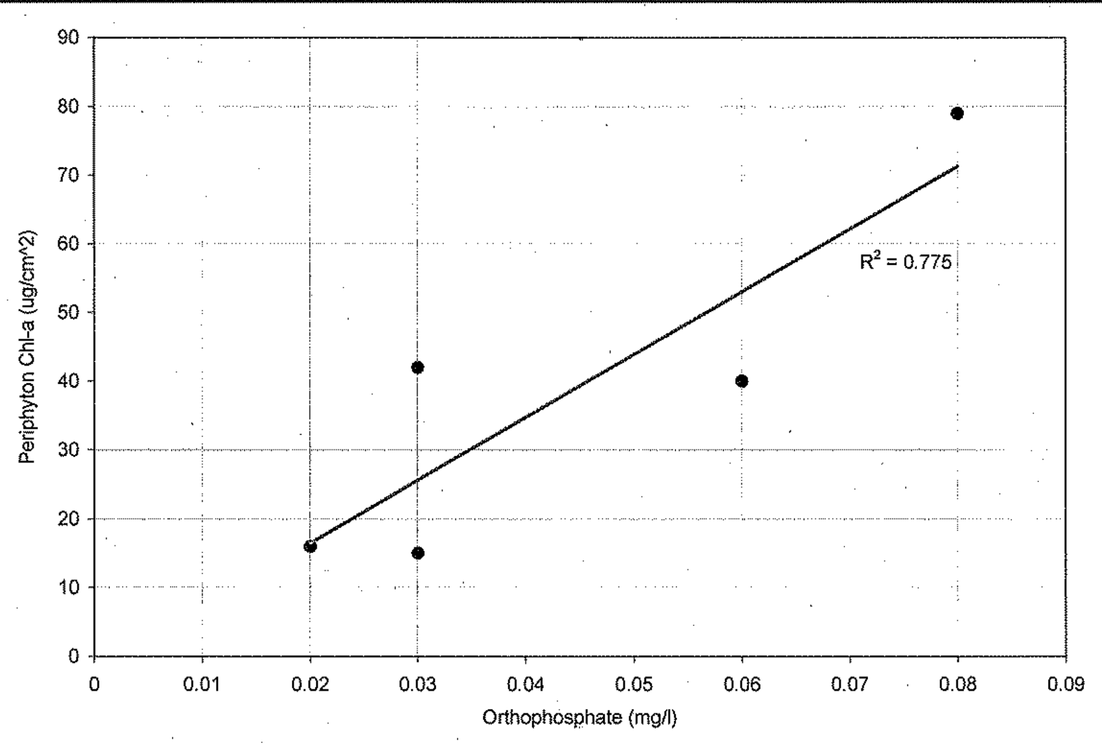

Figure 8. Relationship of dissolved phosphorus to periphyton chlorophyll-a.

Applicable water quality standards. As a perennial waterbody, Middle Fork South Beaver Creek is currently protected for primary contact recreation and warmwater aquatic life uses (Classes A and B, respectively), as well as being protected by the antidegradation policy and general/narrative water quality criteria as defined in Iowa's Water Quality Standards (IAC, 2006). The stream's final designated uses, however, are dependent upon a field-based use attainability analysis (UAA).

The State of Iowa does not have a numeric standard for nutrients in lakes or rivers. However, phosphorus is linked to dissolved oxygen in the stream through excessive plant growth and respiration. Therefore, the state water quality standard for dissolved oxygen in Class B(WW-1) waterbodies (minimum concentration of 5.0 mg/l) serves as an appropriate water quality standard. However, a total phosphorus target for Phase 1 was established using a statistical/modeling approach and is discussed in Appendix D.

Data sources. Water chemistry sampling was performed by Iowa DNR and UHL staff in 2001 and 2003 at two locations (Figure E1). This included multiple grab sample data collection at both sites, continuous temperature and dissolved oxygen monitoring using an autosampler at the downstream site, and event monitoring during surface runoff periods. Data for point source wastewater flows were obtained from National Pollutant

Discharge Elimination System (NPDES) discharge monitoring records. No discharge monitoring records for phosphorus is currently collected at the Ackley WWTP.

Interpreting Middle Fork South Beaver Creek data. Generally speaking, the dissolved oxygen problems in Middle Fork South Beaver do not become apparent in the stream until mid- to late summer, when streamflow is low and temperatures are high. It is during these periods where the physical conditions in the stream (low flow, high heat and temperature, long water residence time) are most conducive to benthic algae, phytoplankton, and macrophyte growth. Continuous autosampler data collected in the early summer (6/22/2003-6/29/2003) show no violations of the minimum dissolved oxygen standard, and daytime-nighttime swings are within an acceptable range (max 24-hour range = 4.2 mg/l) (shown in Figure 9). Daily swings of 10 mg/l dissolved oxygen or greater have been tied to reduced biotic integrity scores in the Iowan Surface Ecoregion (IDNR, 2006).

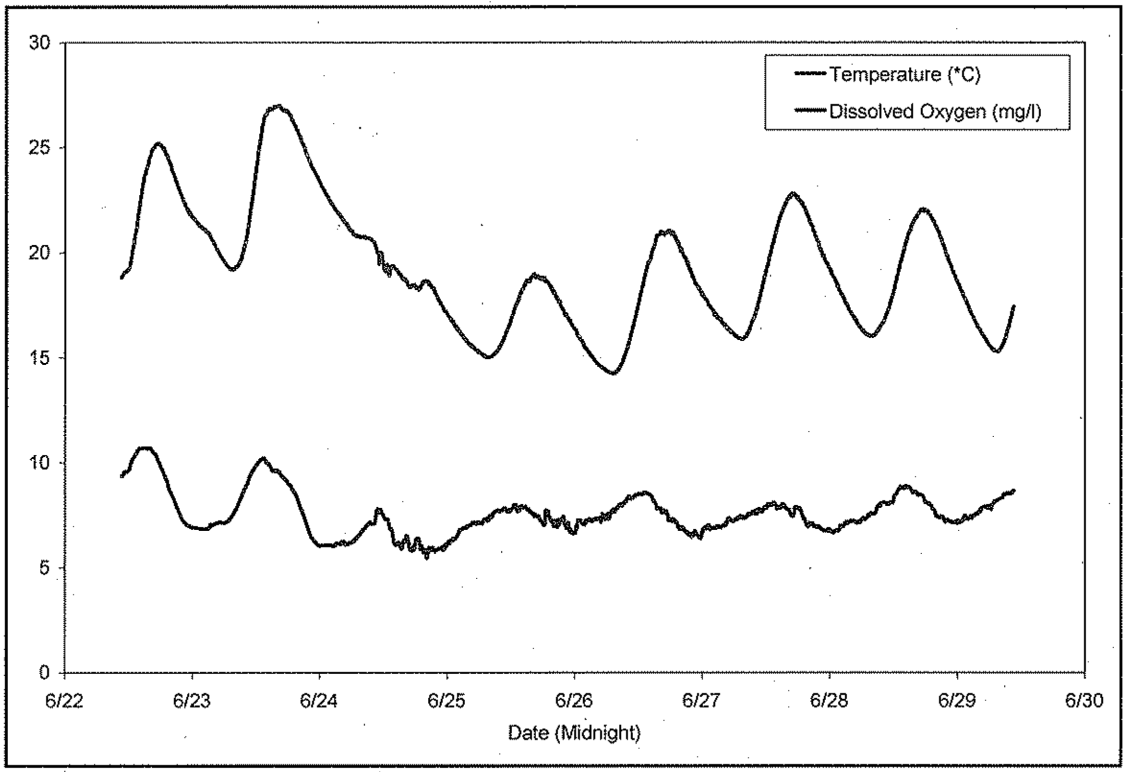

Figure 9. Autosampler data collected at Site 45 in June 2003.

However, continuous autosampler data collected during the late summer period (8/12/2003-8/26/2003) show extreme variations from daytime to nighttime (max 24-hour swing = 21.1 mg/l) and multiple violations of the absolute minimum standard (shown previously in Figure 4). Grab samples for dissolved oxygen during the daytime could easily miss such drastic variations, although data collected at the upstream monitoring site show extremely low levels (1.9-4.3 mg/l) on several occasions.

Total phosphorus concentrations (collected by grab sample) during the monitoring period ranged from 0.02 mg/l to 2.3 mg/l at the upstream site, and 0.08 to 0.6 mg/l at the downstream site. The overall mean total phosphorus concentration in Middle Fork South Beaver was 0.28 mg/l, or 280 µg/l, while the overall median was 0.2 mg/l or 200 µg/l. Seasonal variations in total phosphorus are shown in Figure 10.

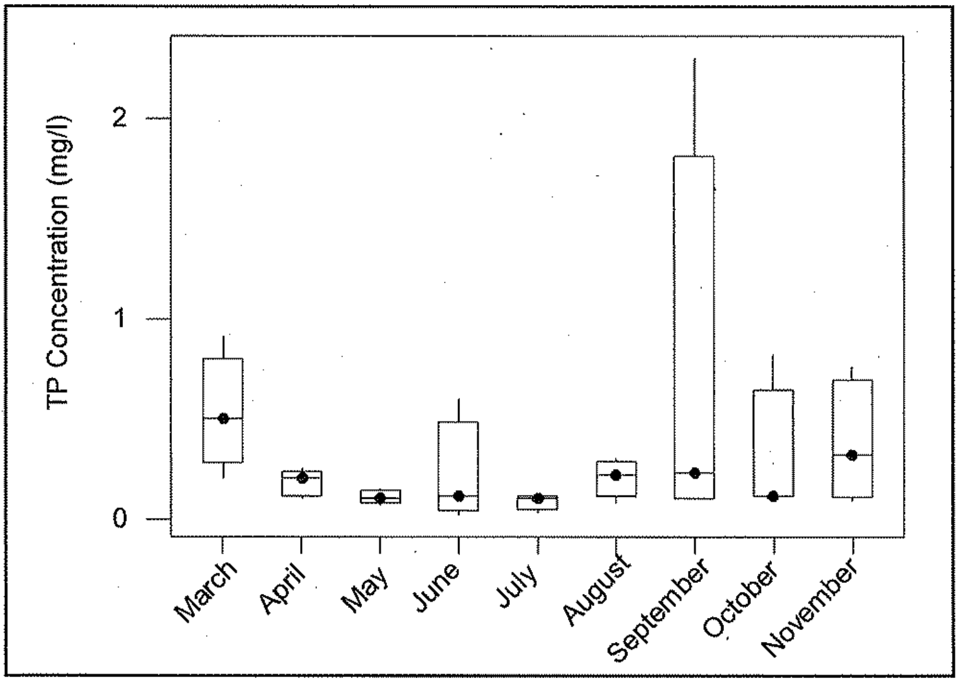

Figure 10. Monthly boxplots for total phosphorus concentrations.

4.2. TMDL Target

General description of the pollutant. Phosphorus is widely recognized as a primary limiting nutrient for plant growth in freshwater aquatic systems (Kalff, 2002). Under normal conditions, phosphorus is scarce in the environment (USEPA, 1999). Naturally-occurring phosphorus exists in rocks and natural phosphorus deposits in the earth's crust and is released by the processes of weathering, leaching, erosion, and mining. Anthropogenic inputs of phosphorus to aquatic ecosystems include synthetic plant fertilizers and waste materials from industrial, sanitary, and livestock production systems. Phosphorus reaches waterbodies via atmospheric deposition, direct discharge, surface runoff, erosion (particulate matter/sediment-attached), and groundwater seepage. In freshwater systems, phosphorus exists in either organic or inorganic forms (USEPA, 1999).

Selection of environmental conditions. The critical environmental conditions in Middle Fork South Beaver Creek occur in late summer and early fall, when stream discharge is low and warm weather persists. Under these conditions, excessive algal growth is encouraged and can have a dramatic effect on in-stream dissolved oxygen concentrations due to the low-flow conditions.

While lethal conditions primarily occur in late summer, plant growth in the stream leading up to these critical conditions occurs throughout the growing season. Therefore, the Phase 1 target for total phosphorus is expressed as an annual loading.

Water body pollutant loading capacity (TMDL). The Phase 1 target for total phosphorus is a maximum load capacity of 17,921 lbs/year. This equates to an average loading capacity of 49.1 lbs/day, with a daily maximum of 142 lbs. These targets are based on reducing in-stream TP concentrations to a sample median of 0.12 mg/l, for reasons discussed in Appendix D.

Figure 11 shows a load duration curve for Phase 1. The target median load varies depending on flow conditions in the stream: at higher streamflows, higher loads of total phosphorus can be assimilated while still meeting the target median of 0.12 mg/l, whereas at low-flow conditions, the stream has a smaller phosphorus load capacity.

Decision criteria for water quality standards attainment. To fully support/attain its Class B(WW-1) designate uses, stream bioassessment scores in Middle Fork South Beaver Creek must meet the 25th percentile reference condition targets (FIBI $\geq$ 44 and BMIBI $\geq$ 59) for the Iowan Surface. Reference scores are subject to change pending additional monitoring data and information collected throughout the ecoregion. Furthermore, dissolved oxygen levels in the stream and other water chemistry parameters must meet state quality standards as defined by the Iowa Code (IAC, 2006) and the Iowa 305(b) Assessment protocols.

4.3. Pollution Source Assessment

Existing load. Annually, phosphorus loads to Middle Fork South Beaver Creek are estimated to be 29,868 lbs per year, or 81.8 lbs/day on average. Measured loads have ranged from 0.1 lbs/day to 16.8 lbs/day at the upstream site, and from 0.5 lbs/day to 237.4 lbs/day at the downstream site. Observed loads are plotted around the existing sample median in Figure 11.

Departure from load capacity. Current in-stream loads exceed Phase 1 target loadings by 40%. This deviation (based on sample median concentrations) is shown in the load duration graph shown in Figure 11.

Identification of pollutant sources. Potential sources of phosphorus to Middle Fork South Beaver Creek were grouped according to the dominant delivery processes which transport the pollutant from the source to the stream. Broadly, these include point source discharges and nonpoint sources; the Ackley wastewater treatment plant is the only permitted point source in the watershed, while nonpoint sources include surface runoff/tile flow (dissolved and sediment-attached phosphorus), illicit or failing household septic systems, cattle in streams, and direct atmospheric deposition (wetfall and dryfall).

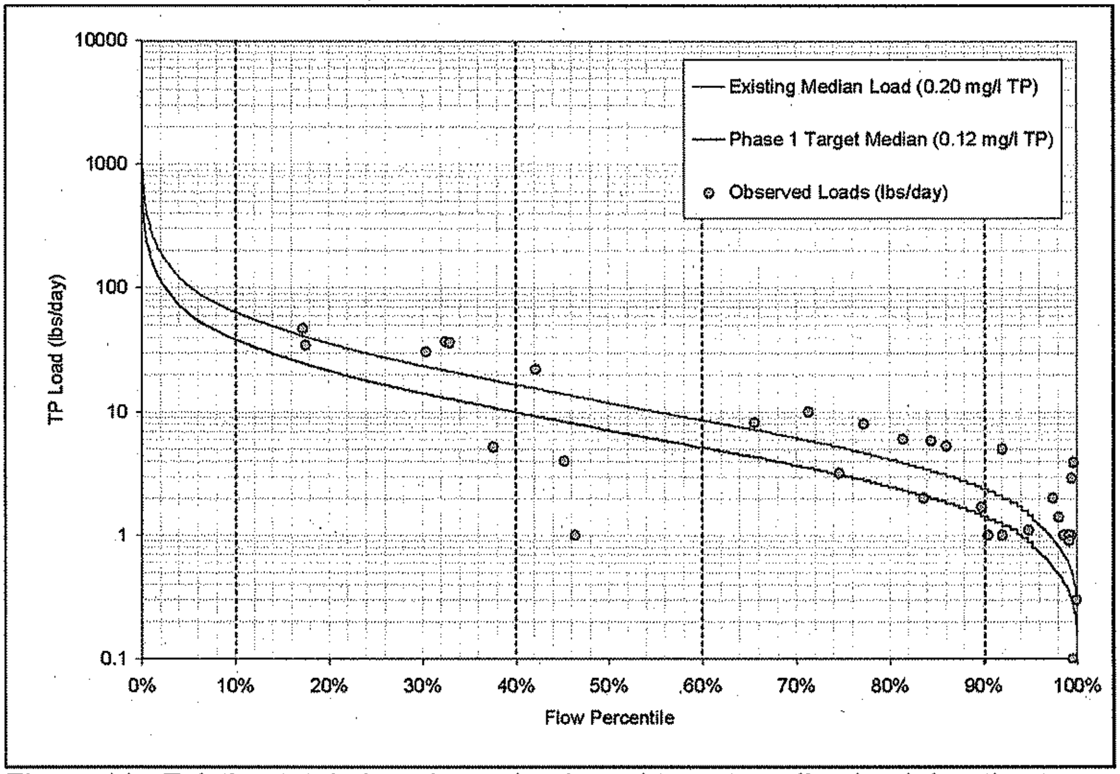

Figure 11. Existing total phosphorus loads and target median load duration curve.

Phosphorus loading to the stream was estimated independently for each source using a variety of methods, which are discussed in detail in Appendix D. Figure 12 shows the estimated proportions of phosphorus loading to the stream by category. Based on these estimates, the majority of phosphorus is transported during rain events by surface runoff as dissolved and sediment-attached phosphorus. Point source contributions also make up a significant fraction of the annual estimated total phosphorus load in the stream, and may dominate during base flow conditions. Cattle with direct access to the stream, failing septics, and atmospheric deposition are estimated to make up relatively insignificant portions of the total annual load.

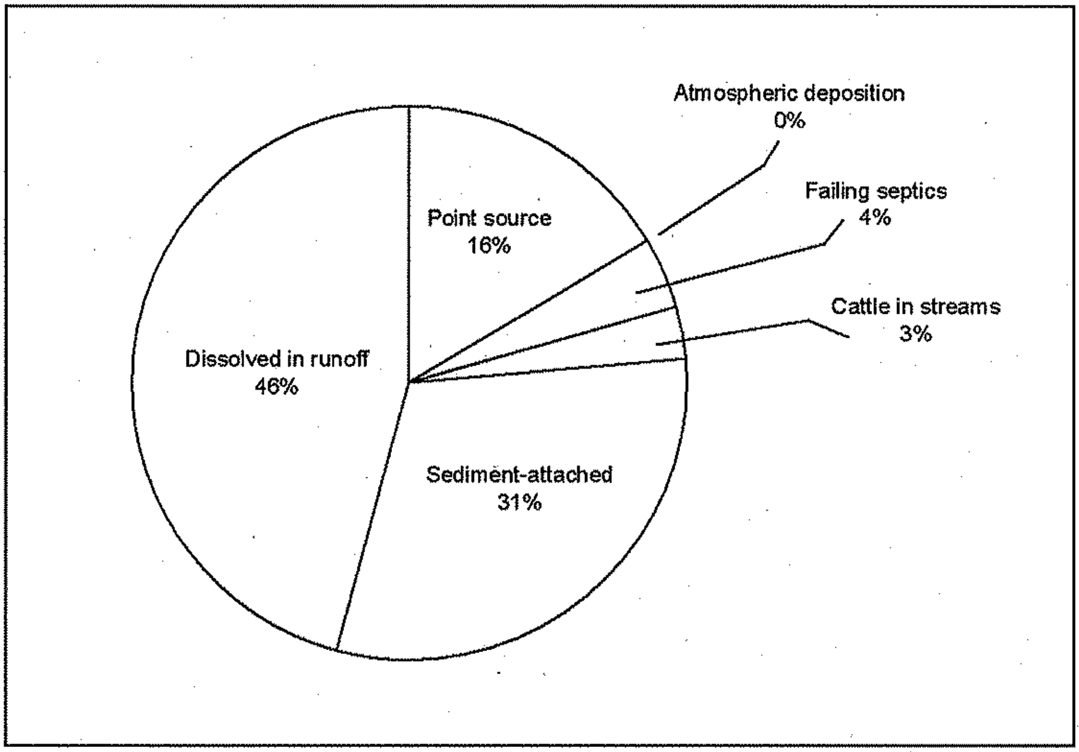

Figure 12. Source distribution of estimated annual phosphorus loading.

Figure 13 shows how the event-driven loads (surface runoff and sediment-attached phosphorus) are distributed spatially throughout the watershed. These estimates were made using the EUTROMOD loading function model as described in Appendix D. This map should assist local land managers in prioritizing surface runoff-based conservation practices at the watershed scale.

Allowance for increases in pollutant loads. No new point source dischargers are anticipated in the watershed, and most of the land available for agriculture is currently being used for that purpose. Neither livestock nor human populations in the watershed can be reasonably predicted at this time, therefore no allowance for a potential increase in phosphorus loading was given.

4.4. Pollutant Allocation

Wasteload allocation. The wasteload allocation represents the fraction of the TMDL apportioned to point sources in the watershed. The City of Ackley wastewater treatment plant is the only permitted point source allowed to discharge to Middle Fork South Beaver Creek, and it discharges to the stream continuously from a three-cell aerated lagoon. The facility does not currently monitor for phosphorus in its final effluent.

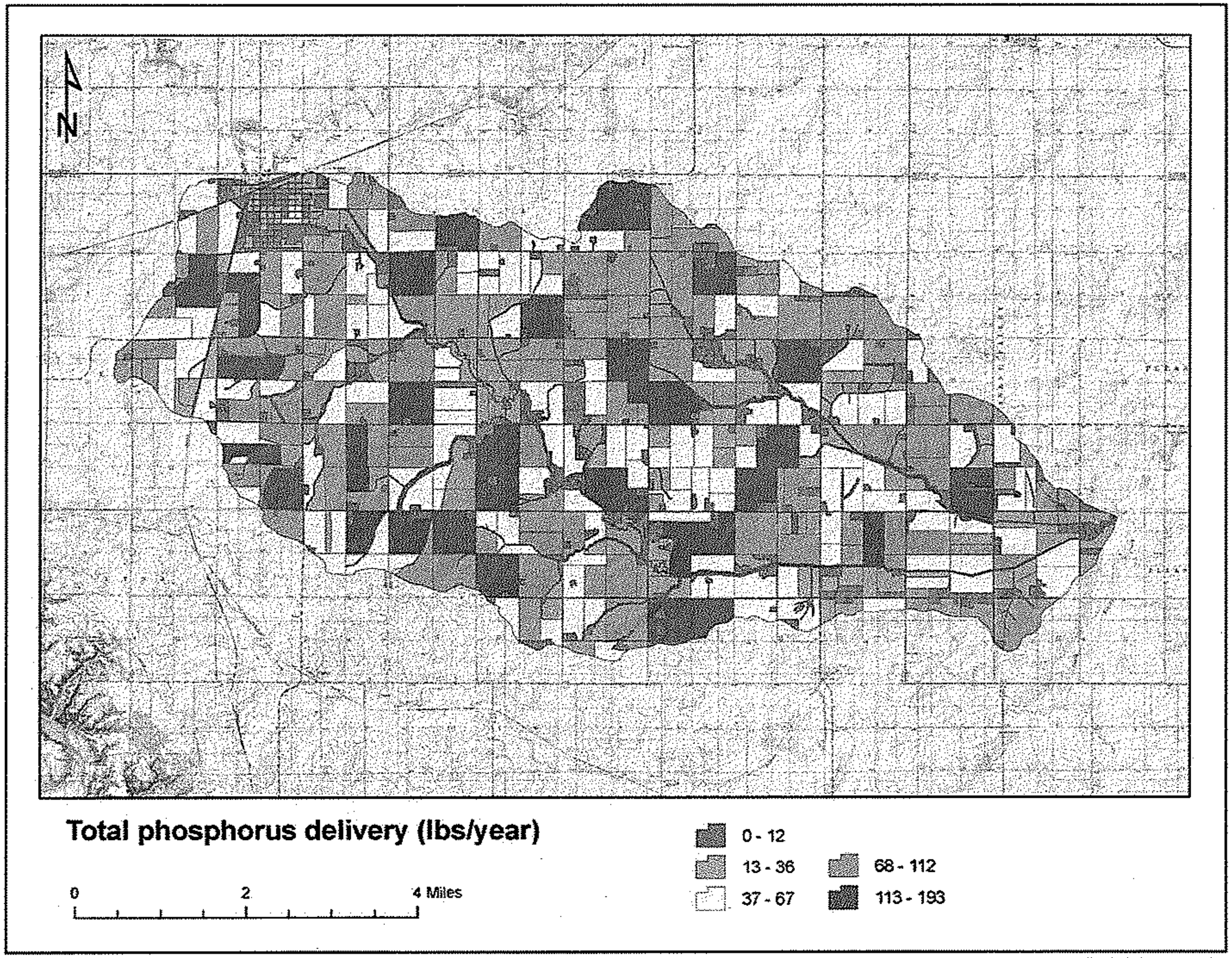

Figure 13. Estimated event-driven phosphorus loading from nonpoint sources (total by field boundary).

For Phase 1, the wasteload allocation for the City of Ackley WWTP is set at its existing discharge load, which is unknown at this time. Thus, typical values for TP loading were taken from literature to determine the Phase 1 WLA. Discharge monitoring requirements for total and dissolved phosphorus are to be implemented into the facility's NPDES permit at next renewal, and effluent limits on phosphorus will be delayed until Phase 2 when discharge monitoring records are available.

Table 4. Wasteload allocation for total phosphorous.

Name	NPDES #	EPA #	Daily Avg. TP WLA† (lbs/ day)	Daily Max. TP WLA† (lbs)	Annual TP WLA (lbs/yr)
City of Ackley WWTP	4201001	IA0035297	13.3	32.9	4,855 lbs/yr

†Based on avg. and max daily flows taken from discharge monitoring records and typical TP concentration of 5 mg/l (Tchobanoglous and Burton, 1991)

Load allocation. The load allocation represents the fraction of the TMDL apportioned to nonpoint sources in the watershed. The difference between the Phase 1 TMDL and the estimated daily average phosphorus loading from point sources was used to set a Phase 1 load allocation 13,066 lbs/year, or 35.8 lbs/day on average. The maximum daily load allocation for nonpoint sources is 109.1 lbs.

Margin of safety. The use of a phased TMDL approach provides an implicit margin of safety to account for uncertainties in nonpoint source phosphorus delivery. Furthermore, estimates of long term phosphorus loading were based on the absence of existing conservation practices which provides an additional implicit margin of safety.

4.5. TMDL Summary

The following equation represents the Phase 1 total phosphorus Total Maximum Daily Load (TMDL) and its components for Middle Fork South Beaver Creek:

TMDL = Load Allocation (nonpoint sources and background) + Wasteload Allocation (point sources) + Margin of Safety (either explicit or implicit)

Total Phosphorus TMDL (142 lbs) = Load Allocation (204.1 lbs) + Wasteload Allocation (32.9 lbs) + Implicit Margin of Safety

Expressed annually,

Total Phosphorus $\text{TMDL}_{\text{Annual}}$ (17,921 lbs/yr) = Load $\text{Allocation}_{\text{Annual}}$ (13,066 lbs/yr) + Wasteload $\text{Allocation}_{\text{Annual}}$ (4,855 lbs/yr) + Implicit Margin of $\text{Safety}_{\text{Annual}}$

Expressed as daily average,

> Total Phosphorus TMDL (49.1 lbs/day) = Load Allocation (35.8 lbs/day) + Wasteload Allocation (13.3 lbs/day) + Implicit Margin of Safety

4.6. Reasonable Assurance

Implementation of point source wasteload allocations and discharge monitoring requirements will be facilitated by the state's NPDES permitting section. Reasonable assurance for the reduction of nonpoint source loading is given by the availability of technical and financial assistance for conservation practices and watershed improvement grants. Funding made available to local stakeholder groups on an annual basis provides an opportunity for local citizens and landowners to seek their own solutions with technical guidance from state and local government agencies. These resources are discussed in more detail in Chapter 5.

5. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in this TMDL. Therefore, this plan is included to be used by local professionals, watershed managers, and citizens for decision-making support and planning purposes. The best management practices (BMPs) listed below represent a comprehensive list of tools that may help achieve water quality goals if applied in an appropriate manner; however, it is up to land managers, citizens, and local conservation technicians to determine exactly how best to implement them.

5.1. General Approach & Reasonable Timeline

Initiative and action by local landowners & citizens are critical to achieving water quality improvements in this watershed, in which all or nearly 100% of the land is privately owned. Citizens and volunteers interested in improving water quality in downstream waterbodies, such as the Cedar and Iowa Rivers, should begin with headwater systems such as Middle Fork South Beaver Creek in Hardin/Grundy County to have the most impact.

Watershed work and improvements to the stream should proceed from the establishment of a comprehensive monitoring system that will adequately characterize daily, seasonal, and annual pollutant loadings in the stream as improvements in the watershed are made. Monitoring data of this nature will supplement point source discharge monitoring required by this TMDL. A suggested monitoring plan is provided in Chapter 6.

Phase 1 reduction targets should begin immediately with the establishment of a monitoring network, and may take anywhere from 5 to 20 years to complete. With a sufficient Phase 1 monitoring dataset and knowledge of conservation practice establishment, water quality standards attainment can be reevaluated and pollutant allocations reassigned if necessary.

5.2. Best Management Practices

Sediment

To reduce sediment delivery to Middle Fork South Beaver Creek, land managers should use conservation practices that provide cover for bare soils and which promote greater infiltration of rainwater. By increasing infiltration, stormwater runoff is reduced along with its erosive impacts on both the upland and in stream channels. These practices should include both management-based BMPs and structural/vegetative BMPs, such as:

- Reduced tillage systems and No-till farming
- Grass waterways
- Riparian forest buffer strips and grass filter strips
- Cattle exclusion from stream channel and banks
- Contour farming and terraces for steep slopes

Establishment of these practices should first focus on high sediment-production source areas that are in close proximity to stream channels, and in areas where concentrated flow occurs in the landscape that can carry field-eroded sediment to stream channels. Figures 14 and 15 show the per-acre sediment delivery and total sediment delivery by subwatershed to assist with overall prioritization in the watershed. Figure 7, shown previously, showed estimated sediment delivery at the field scale to further assist local watershed managers with conservation practice targeting. Identifying dominant source areas of sheet and rill erosion and sediment delivery to the stream is critical to meeting Phase 1 objectives.

In addition, soil conservation practices should be targeted to areas that are currently not treated by an existing practice or structure. A significant number of BMPs already exist in the watershed, as documented by the 2003 watershed survey (Figure 16). In fact, these existing practices are estimated to already have reduced sediment loadings by 12% from long term annual RUSLE estimates (estimated by taking P factor into account). Figure 17 shows the upland areas that are treated by these practices (BMP catchment areas). However, not all conservation practices are equally effective at trapping and removing sediment from surface runoff, and some sites may benefit from a combination of management and structural practices.

Finally, Figure 18 shows which sections of the stream are protected by perennial vegetation, or "buffers." Vegetative buffers are able to intercept, trap, and remove pollutants before they are delivered to the stream, especially when they are made up of native perennials that are properly maintained. They also reduce light availability and temperature in the stream which inhibits algal growth. Stream segments lacking buffers should be prime targets for conservation practice adoption.

Phosphorus

In-stream phosphorus levels will be most effectively reduced by focusing on nonpoint pollutant sources, as they contribute to an estimated 84% of the annual loading. Limitations on point source phosphorus loading will occur following the establishment of required discharge monitoring to determine appropriate reductions.

Of the nonpoint sources, dissolved and sediment-attached phosphorus carried to the stream during rain events makes up the vast majority of annual loading (55% and 37% respectively), while failing septics, cattle in streams, and atmospheric deposition make up smaller portions (5%, 4%, and less than 1% of annual loads respectively). Therefore, efforts should be focused on management and vegetative BMPs that will increase rainfall infiltration and reduce sediment erosion, surface runoff, and nutrient losses during snowmelt and storm events:

- Cover crops
- Nutrient management
- Manure incorporation
- Split fertilizer application
- Controlled drainage systems
- Woodchip/mulch biofilters

- Wetlands and detention ponds
- Soil conservation practices mentioned above

The dissolved fraction dominates over sediment-attached phosphorus loading (13,667 lbs/year vs. 9,162 lbs/year). Figure 19 shows the per-acre annual phosphorus loading from sediment-attached and dissolved delivery by sub-watershed boundary, and Figure 20 shows the total loading by sub-watershed. Figure 13, shown previously, showed the estimated total phosphorus delivery at the field scale.

Analysis shows that if the Phase 1 sediment reduction target (59% from current loads) is achieved, sediment-attached phosphorus delivery would be reduced from 9,162 to 3,756 lbs per year. This alone would reduce overall phosphorus delivery to the stream by 18%. To achieve the remaining 22% reduction called for in Phase 1, event-driven dissolved phosphorus loadings from nonpoint sources and point source discharges ought to be targeted, as they contribute to a majority of the total annual loads.

Financial and Technical assistance

The state of Iowa has numerous programs available to support voluntary water quality improvements. The Iowa DNR Section 319 Nonpoint Source Program (administered cooperatively by the Watershed Improvement Section and IDALS Division of Soil Conservation) provides up to $3 million annually for incentive-based watershed projects across the state. Competitive grants are awarded each year to local groups which are usually assisted technically by county NRCS and Soil and Water Conservation Districts.

Additional funding is available through the state's Watershed Improvement Review Board (WIRB), Watershed Protection Fund (WSPF), and Water Protection Fund (WPF). Federal farm bill programs such as EQIP, WHIP, CREP, and others may also be available. Interested landowners should contact their local NRCS or SWCD offices or the IDNR Watershed Improvement Section for assistance and further information. Contact information for the Hardin and Grundy Soil & Water Conservation Districts is given below.

Grundy County Soil and Water Conservation District
805 West 4th Street, Ste. 2
Grundy Center, IA 50638-1069
319-824-3634

Hardin County Soil and Water Conservation District
840 Brooks Road
Iowa Falls, IA 50126-8008
641-648-3463

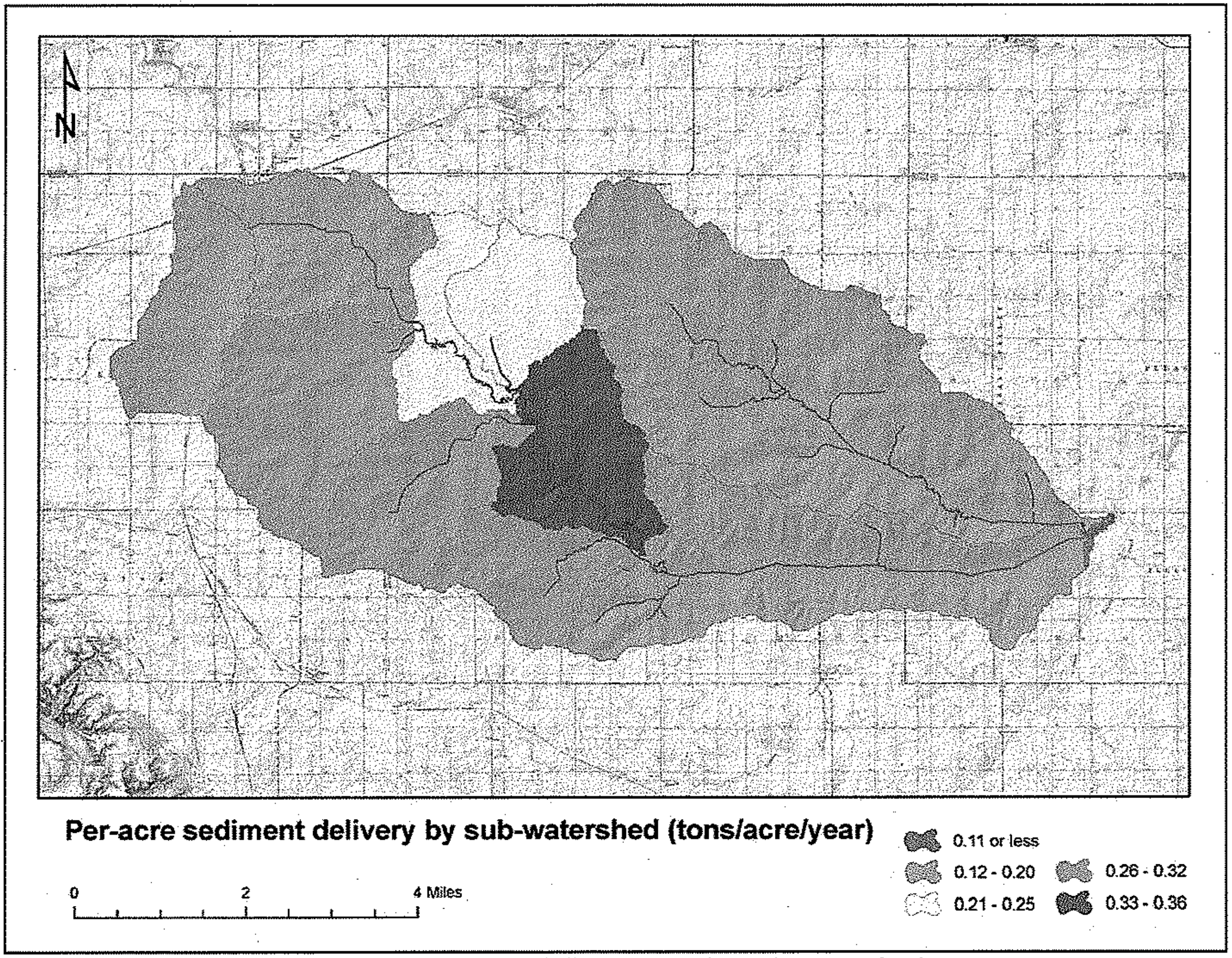

Figure 14. Prioritization map for sediment delivery rates by sub-watershed.

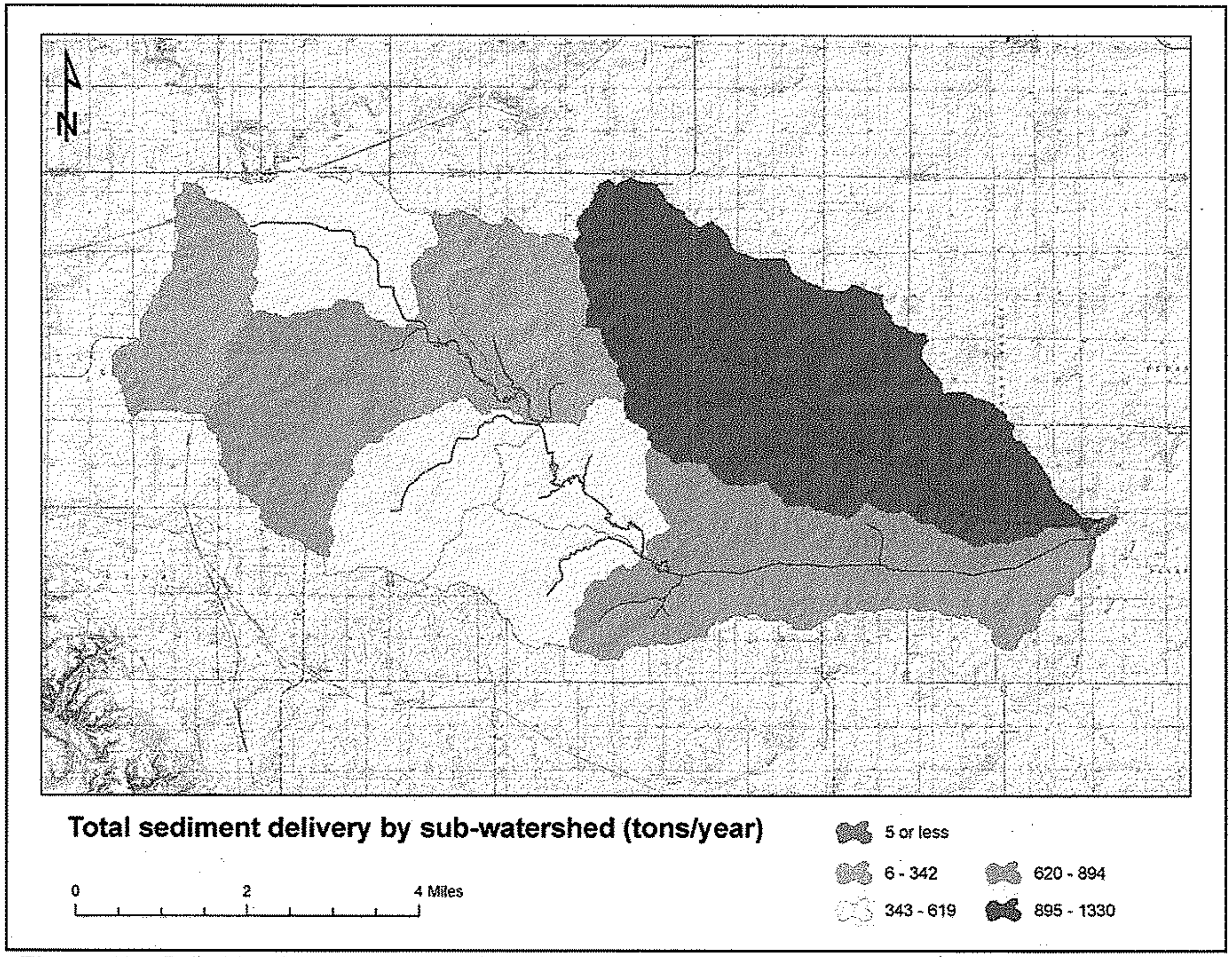

Figure 15. Prioritization map for total sediment delivery by sub-watershed.

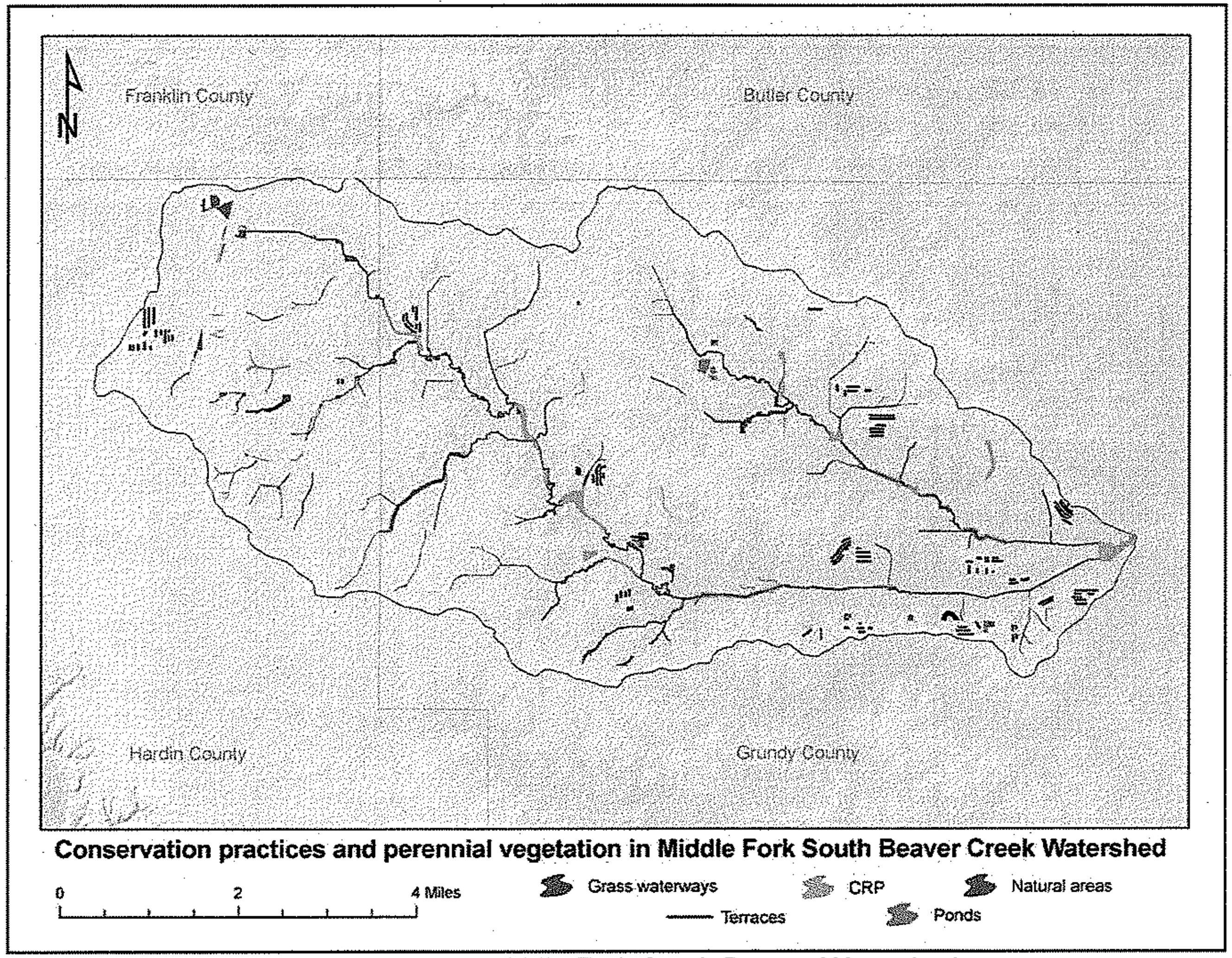

Figure 16. Existing BMPs located in Middle Fork South Beaver Watershed.

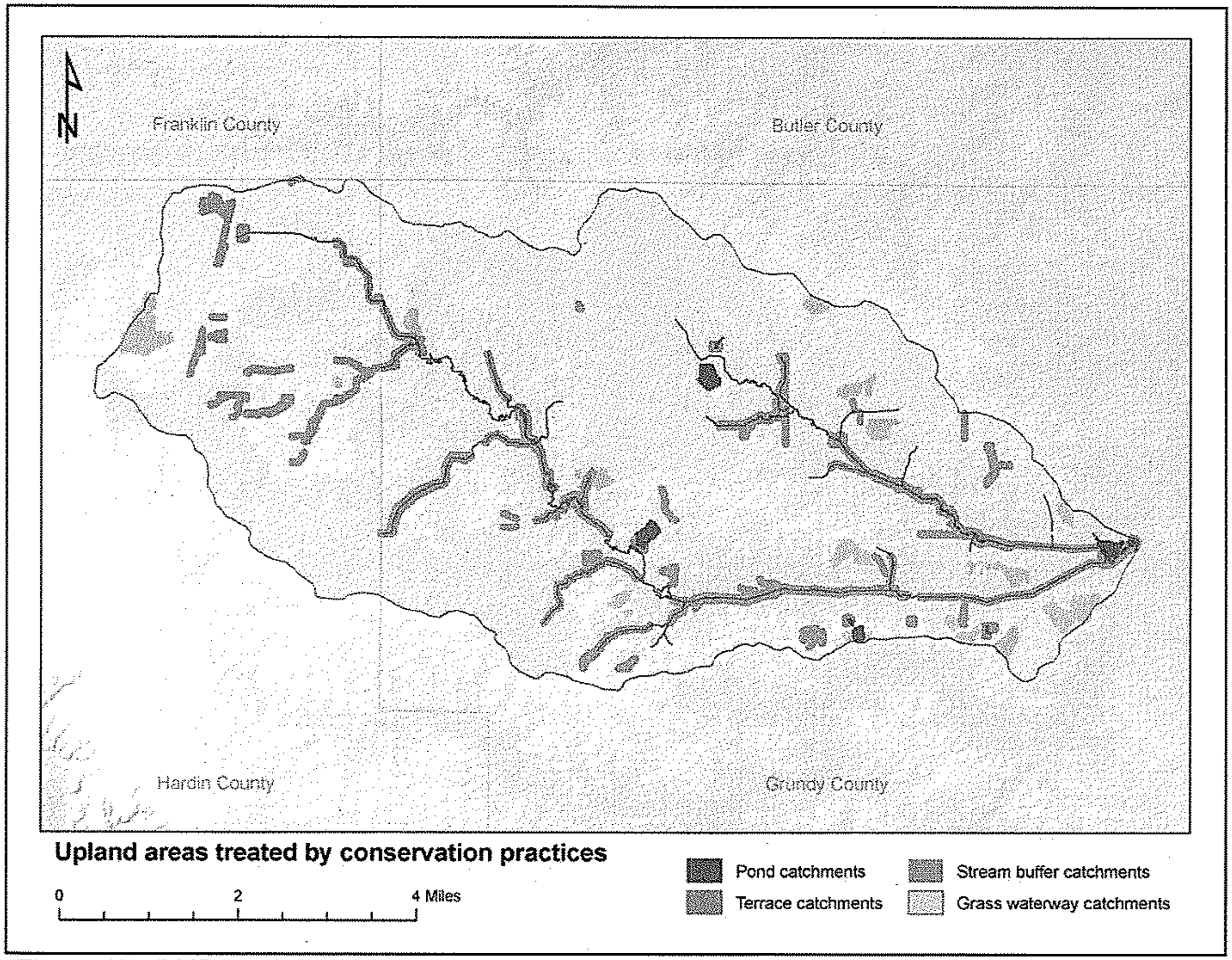

Figure 17. BMP catchment areas treated by conservation practices.

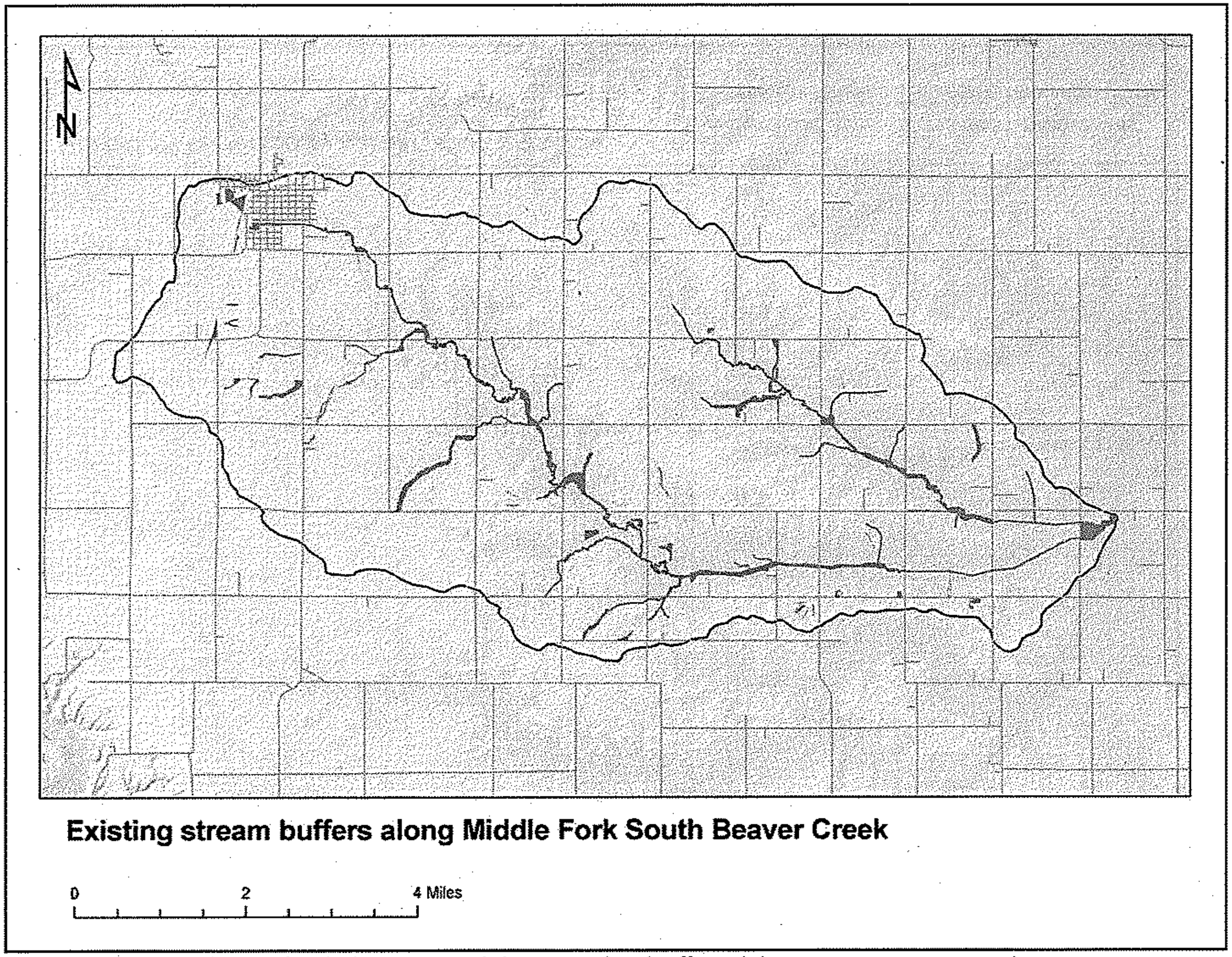

Figure 18. Locations of existing perennial vegetative buffers (shown as green areas).

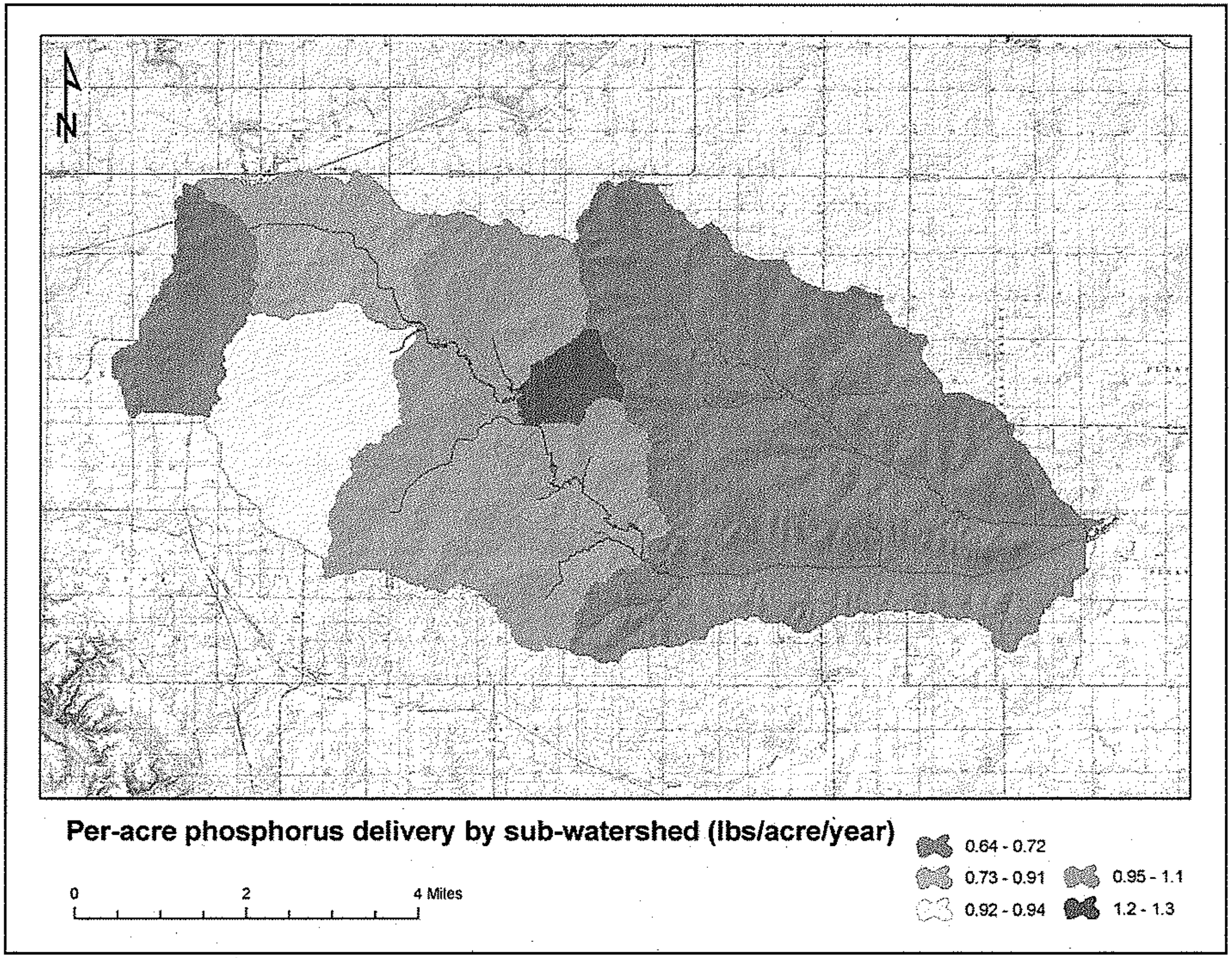

Figure 19. Prioritization map for per-acre nonpoint phosphorus delivery by sub-watershed.

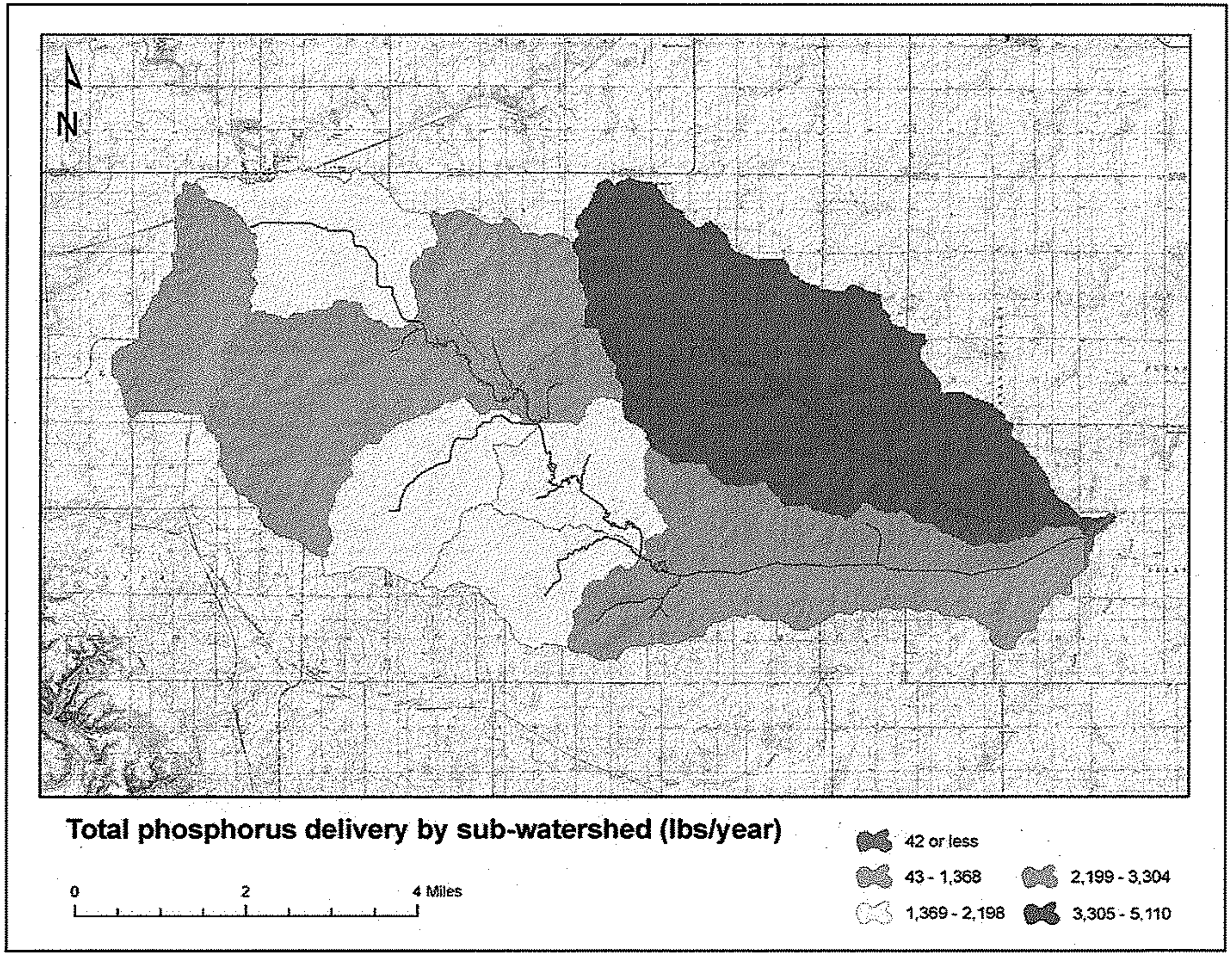

Figure 20. Prioritization map for event-driven nonpoint source phosphorus by sub-watershed.

6. Future Monitoring

Water quality monitoring is a critical element in assessing the current status of water resources and the historical trends. Furthermore, monitoring is necessary to track the effectiveness of water quality improvements made in the watershed and document the status of progress towards achieving total maximum daily loads.

6.1. Monitoring Plan to Track TMDL Effectiveness

Any future monitoring in the Middle Fork South Beaver Creek watershed should use the monitoring plan identified in Table 5 as a starting point. This monitoring may be agency led or volunteer based. The Iowa DNR Watershed Monitoring and Assessment Section administers a citizen-based water quality monitoring program to train willing volunteers. Citizen volunteers who wish to form a monitoring network may submit credible data used for 303(d) purposes only with the preparation of an approved water quality monitoring plan (a.k.a., Quality Assurance Project Plan or QAPP) in accordance with Iowa Code 567—61.10(455B) through 567—61.13(455B).

6.2. Idealized Plan for Future Watershed Projects

The purpose of this section is to outline what an appropriate monitoring plan would look like for Middle Fork South Beaver Creek should any watershed monitoring groups become active and aspire to collect water quality data in the future. Financial and logistical constraints may prohibit full deployment of this plan, but if resources allow this plan would provide a rather comprehensive dataset for assessment purposes. Local knowledge should drive the more specific details of all future monitoring efforts.

To adequately monitor the stream's health as it relates to the 303(d) biological impairment, there are five major components that are needed. These five components are listed in Table 5, along with more specific details on the parameters, locations, and sampling frequencies. Figure 21 shows the locations of proposed "snapshot" monitoring sites to support future Qual2K modeling efforts.

Table 5. Ideal monitoring plan for future watershed projects.

Component	Sample Frequency	Locations	Parameters/Details
1. Point source phosphorus monitoring	Once per week	Final effluent of Ackley WWTP	Grab sample for total phosphorus and dissolved phosphorus, to be implemented into NPDES permit monitoring requirements
2. Water chemistry sampling	Bi-weekly from March to November	STORET sites #11420001 and #11380003 (TMDL Sites 47 and 45)	All common parameters listed in Appendix A of the Iowa Water Monitoring Plan 2000 (http://wqm.igsb.uiowa.edu/publications/plan2000.htm)
3. Physical habitat assessments	Annually, at low-flow conditions	STORET sites #11420001 and #11380003 (TMDL Sites 47 and 45)	Monitoring should be done in accordance with the *Habitat Evaluation Procedures for Wadeable Streams and Rivers in Iowa* available from the IDNR Watershed Monitoring and Assessment Section.
4. Continuous dissolved oxygen and flow measurements	Continuously (6-minute intervals) from June to October	STORET sites #11420001 and #11380003 (TMDL Sites 47 and 45)	Continuous streamflow and dissolved oxygen autosampler deployment according to UHL protocols
5. "Snapshot" monitoring	Twice per summer; once during early season high flows and once in late season low flows	See Figure 21	To serve needs of Qual2K modeling, collect all common water chemistry parameters (as in #2) at each site shown in Figure 21 when a full 24-hour period of continuous dissolved oxygen data is available for both upstream and downstream boundary sites (as in #4). Also, physical parameters to be collected at each site shown in Figure 21 include streamflow, avg. width, avg. depth, and avg. velocity.

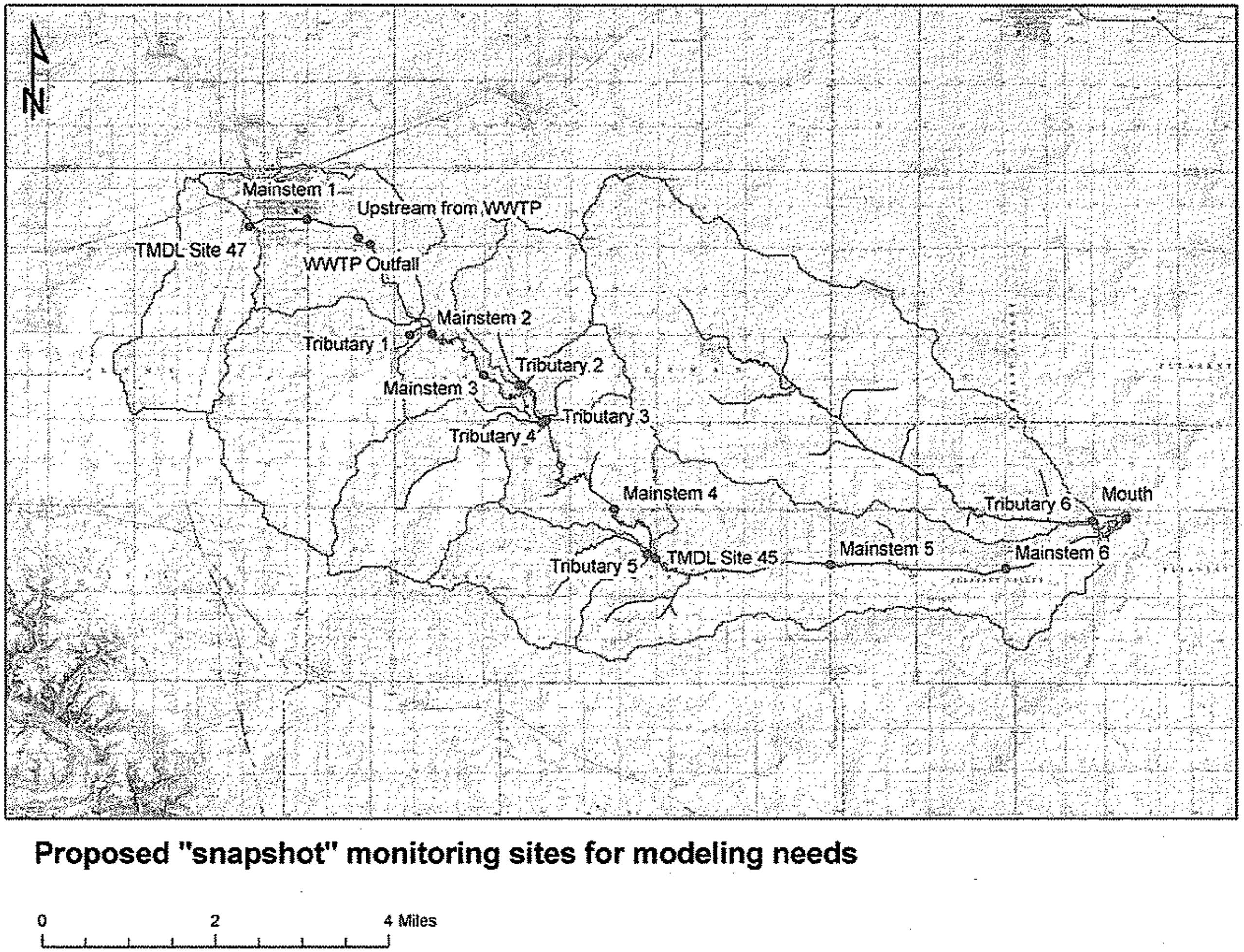

Figure 21. Location of monitoring sites to support future Qual2K modeling efforts.

7. Public Participation

Public involvement is important in the TMDL process since it is the land owners, tenants, and citizens who directly manage land and live in the watershed that determine the water quality in Middle Fork South Beaver Creek. During the development of this TMDL, every effort was made to ensure that local stakeholders were involved in the decision-making process to agree on feasible and achievable goals for the water quality in Middle Fork South Beaver Creek.

7.1. Public Meetings

Initial notice of the TMDL development was given to the public on July 12, 2004 at a city council meeting in the city of Ackley. A final public meeting was held on August 7, 2007 in Ackley to present and discuss the final TMDL. This meeting was attended by local city officials, NRCS, local citizens and landowners, and one member of the media.

7.2. Written Comments

No public comments were received on the draft TMDL.

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9. Appendices

Appendix A --- Glossary of Terms and Acronyms

303(d) list: Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface water bodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."

305(b) assessment: Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public water bodies ability to support their general and designated uses. Those bodies of water which are found to be not supporting or just partially supporting their uses are placed on the 303(d) list.

319: Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.

AFO: Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed become concentrated.

Base flow: The fraction of discharge (flow) in a river which comes from ground water.

BMIBI: Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.

BMP: Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.

CAFO: Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof, and not allowed to discharge manure to a water of the state.

Credible data law: Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate.

Cyanobacteria (blue-green algae):	Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.
Designated use(s):	Refer to the type of economic, social, or ecologic activities that a specific water body is intended to support. See Appendix B for a description of all general and designated uses.
DNR (or IDNR):	Iowa Department of Natural Resources.
Ecoregion:	A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.
EPA (or USEPA):	United States Environmental Protection Agency.
FIBI:	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
FSA:	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
General use(s):	Refer to narrative water quality criteria that all public water bodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.
GIS:	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
Gully erosion:	Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.
HEL:	Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

Integrated report: Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public water bodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.

LA: Load Allocation. The fraction of the total pollutant load of a water body which is assigned to all combined *nonpoint sources* in a watershed. (The total pollutant load is the sum of the waste load and load allocations.)

Load: The total amount (mass) of a particular pollutant in a waterbody.

MOS: Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.

MS4 Permit: Municipal Separate Storm Sewer System Permit. An NPDES license required for some cities and universities which obligates them to ensure adequate water quality and monitoring of runoff from urban storm water and construction sites, as well as public participation and outreach.

Nonpoint source pollution: A collective term for contaminants which originate from a diffuse source.

NPDES: National Pollution Discharge Elimination System, which allows a facility (e.g. an industry, or a wastewater treatment plant) to discharge to a water of the United States under regulated conditions.

NRCS: Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.

Periphyton: Algae that are attached to substrates (rocks, sediment, wood, and other living organisms).

Phytoplankton: Collective term for all self-feeding (photosynthetic) organisms which provide the basis for the aquatic food chain. Includes many types of algae and cyanobacteria.

Point source pollution:	A collective term for contaminants which originate from a specific point, such as an outfall pipe. Point sources are generally regulated by an NPDES permit.
PPB:	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).
PPM:	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).
Riparian:	Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.
RUSLE:	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
Secchi disk:	A device used to measure transparency in water bodies. The greater the secchi depth (measured in meters), the more transparent the water.
Sediment delivery ratio:	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion which actually reaches a water body of concern.
Seston:	All particulate matter (organic and inorganic) in the water column.
Sheet & rill erosion	Soil loss which occurs diffusely over large, generally flat areas of land.
SI:	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a water body can be determined from cause-and-effect relationships.
Storm flow (or stormwater):	The fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. *Storm water* generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.
STP:	Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent suitable for release to public waters.

SWCD: Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.

TMDL: Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a water body can tolerate while still meeting its general and designated uses.

TSI (or Carlson's TSI): Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.

TSS: Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.

Turbidity: The degree of cloudiness or murkiness of water caused by suspended particles.

UAA: Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular water body. (See Appendix B for a description of all general and designated uses.)

UHL: University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring and impaired water assessments.

USGS: United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's water bodies.

Watershed: The land (measured in units of surface area) which drains water to a particular body of water or outlet.

WLA: Waste Load Allocation. The fraction of waterbody loading capacity assigned to point sources in a watershed. Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.

WQS:	Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.
WWTP:	Waste Water Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent suitable for release to public waters or land application.
Zooplankton:	Collective term for all animal plankton which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

Appendix B --- General and Designated Uses of Iowa's Waters

Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B1) which may apply, and a water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

Table B1. Designated use classes for Iowa water bodies.

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

Appendix C --- Water Quality Data

Data and information for Middle Fork South Beaver Creek is relatively sparse compared to other larger river systems and lakes in Iowa. However, a sufficient amount of data has been collected from the stream to adequately diagnose the stream's impairment and its causes. The first known monitoring of the stream was done in 1975 at two locations, shown in Figure E2. Table C1 gives the data from the Legacy STORET system. UHL water chemistry sampling from 2001 and 2003 is summarized in Tables C2 and C3. Data from the biological assessment by IDNR in 2001 are shown in Table C4.

Table C1. Legacy STORET data collected on September 22, 1975.

PARAMETER	US20	Wellsburg
ALKALINITY, PHENOLPHTHALEIN (MG/L)	0	2
ALKALINITY, TOTAL (MG/L AS CACO3)	278	184
AMMONIA, UNIONZED (MG/L AS N)	0.00068	0.00064
BOD 5 DAY (MG/L)	7	2
CHLORIDE,TOTAL IN WATER (MG/L)	120	39
COD LOWLEVEL (MG/L)	52	22
DO (MG/L)	9.3	12.4
DO SATUR (PERCENT)	91.3	124.0
FECAL COLIFORM	69000	720
NITRATE NITROGEN, TOTAL (MG/L AS N)	1.3	2.6
NITRITE NITROGEN, TOTAL (MG/L AS N)	0.044	0.038
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	0.05	0.01
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	1.5	0.35
PH LAB SU	7.7	8.35
PHOSPHATE, TOTAL (MG/L AS PO4)	5.2	0.03
RESIDUE DISS-105 C (MG/L)	864	433
RESIDUE TOT NFLT (MG/L)	33	21
RESIDUE, TOTAL (MG/L)	897	454
SPECIFIC CONDUCTANCE (UMHOS/CM)	1290	622

Table C2. Data collected by UHL for the DNR in 2001 and 2003.

Collection Date	NH3 as N (mg/l)	CBOD (20 day) (mg/l)	CBOD (5 day) (mg/l)	DO (mg/l)	pH	Temp (deg C)	Filterable Ortho. as P (mg/l)	Ortho. as P (mg/l)
Event Sampling - Site 45								
3/14/2001	1.6		16	11.3	7.8	0.3	0.6	
3/19/2001	0.6		2	10.4	7.5	0.7	0.4	
3/13/2003	2.8	17		11.7	8	1.4		0.77
4/8/2003 (grab)	0.63	7		14.6	8.3	5.9		0.11
11/5/2003 (grab)				12.3	7.5	3		
11/4/2003 (post-peak)	0.31	15						0.39
11/4/2003 (pre-peak)	1.1	20						0.56
Monthly Sampling - Site 45								
3/6/2001	3.1		2	10.2	8.4	0.5	0.5	
4/5/2001	0.3		<2	10.9	7.9	7.1	0.1	
5/10/2001	<0.1		<2	10.4	8	13.8	<0.02	
6/7/2001	<0.1		<2	9.5	8	13.7	0.03	
7/5/2001	<0.1		<2	10.4	8.4	19	0.09	
8/2/2001	0.1		3	7.1	8.1	27.2	0.12	
9/14/2001	0.13		2	9.6	8.2	13.6		0.12
10/8/2001	<0.05		<2	13.8	8.6	11.4	0.08	
11/1/2001	0.4		<2	13.8	8.3	13	0.08	
3/19/2003	1.9	12		12.4	8.2	1.6		0.2
4/1/2003	0.16	20		16.7	8.5	13.7		0.09
5/15/2003	0.07	3		10.4	8	11.4		0.07
6/12/2003	<0.05	29		10.1	8.1	15.3		0.04
7/16/2003	<0.05	5		9.5	8.1	18.2		0.06
8/13/2003	<0.05	5		11.2	8.2	21.6		0.03
9/10/2003	<0.05	10		9.6	8.1	19.5		0.03
10/13/2003	<0.05	8		10.3	8.3	12.1		0.05
Monthly Sampling - Site 47								
3/6/2001	4.6		5	7.6	8	2	0.3	
4/5/2001	<0.1		<2	11.2	7.7	6.2	<0.1	
5/10/2001	<0.1		<2	11.1	7.7	12.3	0.05	
6/7/2001	<0.1		<2	10.3	7.7	12.8	<0.02	
7/5/2001	<0.1		<2	11.4	8.1	16	0.03	
8/2/2001	0.4		6	4.3	7.6	27.6	0.1	
9/14/2001	0.1		30	2.4	7.7	14.2		<0.01
10/8/2001	<0.05		<2	11	8.1	11.4	0.05	
11/1/2001	0.06		<2	9.1	7.7	12.7	0.07	
3/19/2003	0.27	18		11.6	8	1.7		0.05
4/1/2003	<0.05	19		13.3	8	9.3		<0.05
5/15/2003	<0.05	3		12.7	7.9	12.1		<0.05
6/12/2003	<0.05	26		11.7	7.9	14.3		<0.02
7/16/2003	<0.05	<2		9.6	7.8	16.9		0.03
8/13/2003	<0.05	7		3.8	7.8	20.7		0.14
9/10/2003	<0.05	70		11.2	8.9	19.5		0.06
10/13/2003	<0.05	12		1.9	7.5	11.3		0.07

Table C2 (continued).

Collection Date	Flow Rate (cfs)	NO3 + NO2 as N (mg/l)	Silica as SiO2 (mg/l)	Specific Conductance (umhos/cm)	TKN as N (mg/l)	Total Phosphate as P (mg/l)	TSS (mg/l)	TVSS (mgl)
Event Sampling - Site 45								
3/14/2001	15.3	8.4		390	4.3	0.8	120	
3/19/2001	88	9.2		410	1.9	0.5	91	
3/13/2003	2.1	4.6	9.7	580	4.9	0.91	9	3
4/8/2003 (grab)	7.8	8.7		670	1.6	0.22	19	7
11/5/2003 (grab)	4.4							
11/4/2003 (post-peak)		9		440	1.5	0.49	34	7
11/4/2003 (pre-peak)		4.5		640	3.3	0.76	94	18
Monthly Sampling - Site 45								
3/6/2001	4	8.2		770	4.6	0.6	11	
4/5/2001	34.7	15		550	1.3	0.2	47	
5/10/2001	37	19		580	0.5	0.1	36	
6/7/2001	36.3	21		610	0.1	0.1	32	
7/5/2001	10	18		600	0.4	< 0.1	9	
8/2/2001	2	4.6		770	1.8	0.3	21	
9/14/2001	8	10		710	1.1	0.1	21	
10/8/2001	6	9.5		680	0.61	0.11	6	
11/1/2001	8.2	11		770	0.87	0.15	8	
3/19/2003	3.2	4.7	7.6	600	2.9	0.28	13	4
4/1/2003	1.7	9.2		680	1.1	0.25	14	4
5/15/2003	47.1	17		650	0.68	0.15	37	5
6/12/2003	30.7	19		690	0.55	0.13	35	5
7/16/2003	22.1	17		760	0.55	0.12	21	4
8/13/2003	2	4.7		570	0.91	0.08	7	2
9/10/2003	1	3.3		600	0.89	0.1	24	6
10/13/2003	0.9	6.5		820	0.74	0.11	16	4
Monthly Sampling - Site 47								
3/6/2001	< 1	7		780	5.7	0.4	< 1	
4/5/2001	5.8	15		600	0.7	0.1	11	
5/10/2001	5.3	21		690	< 0.1	< 0.1	3	
6/7/2001	5.2	23		710	0.9	0.6	9	
7/5/2001	1.4	23		690	0.5	< 0.1	8	
8/2/2001	0	1.8		430	1.8	0.2	26	
9/14/2001	1	0.9		860	2.5	0.36	28	
10/8/2001	1	12		740	0.69	0.11	42	
11/1/2001	1	9.1		1200	0.65	0.09	31	
3/19/2003	0.3	4.5	8.2	580	1.8	0.2	24	10
4/1/2003	1	9.1		790	0.58	0.12	2	< 1
5/15/2003	5	18		740	0.52	0.07	26	3
6/12/2003	3.9	19		810	0.42	0.02	2	< 1
7/16/2003	2.9	13		870	0.3	0.03	3	1
8/13/2003	1.1	< 0.1		450	1.1	0.24	23	4
9/10/2003	< 1	< 0.1		490	16	2.3	180	80
10/13/2003	0.1	< 0.1		450	2.6	0.82	67	20

Table C3. Data from samples collected during auto sampler deployments at site 45 in 2003.

Test Description	Location *	6/23/2003	6/30/2003	8/13/2003	8/13/2003 (duplicate)	8/20/2003	8/27/2003
Flow Rate (cfs)		11.2	21.3	2	2.4	1.7	1.7
TDS (mg/l)		370	410	360		330	360
TSS (mg/l)		15	52	7	28	42	39
TVSS (mg/l)		4	7	2	9	18	10
Turbidity (NTU)		6	16	5.5		17	18
DO (mg/l)		9.2	9.3	11.2	11.7	12.5	7.6
CBOD (20 day) (mg/l)		6	7	5	8	<2	35
Field pH		8	8	8.2	8.3	8.6	8.2
Field Temp. (deg. C)		19.1	18	21.6	22.3	25.6	21.2
NH3 Nitrogen as N (mg/l)		<0.05	<0.05	<0.05	0.06	<0.05	<0.05
NO3 + NO2 Nitrogen as N (mg/l)		17	18	4.7	4.7	2.5	2.9
TKN (mg/l)		0.6	0.71	0.91	2.2	2.6	1.8
Orthophosphate as P (mg/l)		0.08	0.06	0.03	0.03	<0.02	0.03
Total Phosphate as P (mg/l)		0.09	0.11	0.08	0.31	0.22	0.27
Silica as SiO2 (mg/l)		11	12	4.2		1.6	7
Spec. Cond. (umhos/cm)				570			
Chloride (mg/l)		24	25	35		39	40
Chlorophyll A (ug/cm2)	periphyton	79	40	15		16	42
Chlorophyll A (ug/cm2)	sediment	42	11	4.4		17	80
Chlorophyll A (ug/l)		15	31	37		360	91
Chlorophyll B (ug/cm2)	periphyton	17	2.3	1.1		2.4	0.6
Chlorophyll B (ug/cm2)	sediment	3.2	0.1	0.2		<0.1	0.3
Chlorophyll B (ug/l)		2	2	<1		1	<1
Chlorophyll C (ug/cm2)	periphyton	0.9	1.6	0.7		0.5	1.3
Chlorophyll C (ug/cm2)	sediment	<0.1	<0.1	<0.1		<0.1	1.2
Chlorophyll C (ug/l)		<1	<1	3		28	4
Corr. Chl. A (ug/cm2)	periphyton	71	37	13		14	32
Corr. Chl. A (ug/cm2)	sediment	26	5.9	2.1		11	50
Corr. Chl. A (ug/l)		13	24	33		320	84
Pheophytin (ug/cm2)	periphyton	11	3.7	2.7		2.2	13
Pheophytin (ug/cm2)	sediment	26	7.7	3.6		9.6	45
Pheophytin (ug/l)		3	11	4		40	7
Sample Volume (ml)	periphyton	265	226	130		80	85
Sample Volume (ml)	sediment	150	232	36		110	120
Filter Volume (ml)	periphyton	30	40	10.4		30	20
Filter Volume (ml)	sediment	15	45	10.4		10	15

*Samples were collected in the water column unless otherwise noted.

Table C4. Biological information collected in 2001.

	Site 45 8/14/01	Site 47 8/14/01
Fish		
Stonecat	6	
Bigmouth Shiner	21	
Blacknose Dace	9	7
Bluntnose Minnow	46	5
Central Stoneroller	19	181
Common Carp	7	
Creek Chub	27	30
Fathead Minnow		6
Sand Shiner	5	
Spotfin Shiner	19	
Johnny Darter	13	
Golden Redhorse	34	
Shorthead Redhorse	3	
White Sucker	16	10
Bluegill	2	1
Green Sunfish	13	28
Largemouth Bass	4	
Smallmouth Bass	13	
Total Fish	258	268
Benthic Macroinvertebrates		
Basommatophora	16	54
Coleoptera	17	18
Decapoda	3	3
Diptera (Chironomidae)	257 (252)	128 (120)
Ephemeroptera	68	2
Hemiptera	21	12
Isopoda		1
Odonata	18	38
Pharyngobdellida	1	7
Plecoptera	1	
Rhynchobdellida		6
Trichoptera	56	
Tricladida	30	
Hydracarina		3
Oligochaeta	1	113
Total Invertebrates	891	385
Stream Properties		
Flow (cfs), DO (mg/l), Temp (deg. C)	1.2, 6.3, 17.1	<0.1, 7.5, 19.5
Max. Depth, Avg. Depth (ft)	3.4, 0.6	2.3, 0.3
Average Width (ft)	20	12
% Pool, Riffle, Run	84, 5, 11	100, 0, 0
% Gravel, Cobble, Boulder	18, 2, 0	8, 4, 0
% Fines (sand, silt, soil, clay)	76	46

Appendix D --- Modeling, Equations, and Methodology

A variety of techniques were used in the development of this TMDL to estimate stream flow, pollutant loads, and derive statistical relationships. These are discussed in detail below.

Estimation of streamflow using a drainage area-normalized approach

Stream discharge records (daily minimum, maximum, and mean) for Beaver Creek at New Hartford, IA (USGS Site #05463000) were obtained from the online USGS database. For any given point along Middle Fork South Beaver Creek, the ratio of watershed drainage area at that point to the drainage area at the downstream USGS gaging site was used to estimate the area-normalized flows in Middle Fork South Beaver Creek.

On-site flow measurements taken during field sampling by University Hygienic Lab staff were then used to validate the estimated flows. Correlation coefficients between observed and predicted flows were 0.93 at the upstream monitoring site (Site 47) and 0.96 at the downstream site (Site 45). The correlation coefficient for the pooled data (both upstream and downstream sites) was 0.98 and was statistically significant with p = 0.000. Plots of observed vs. predicted values are shown below.

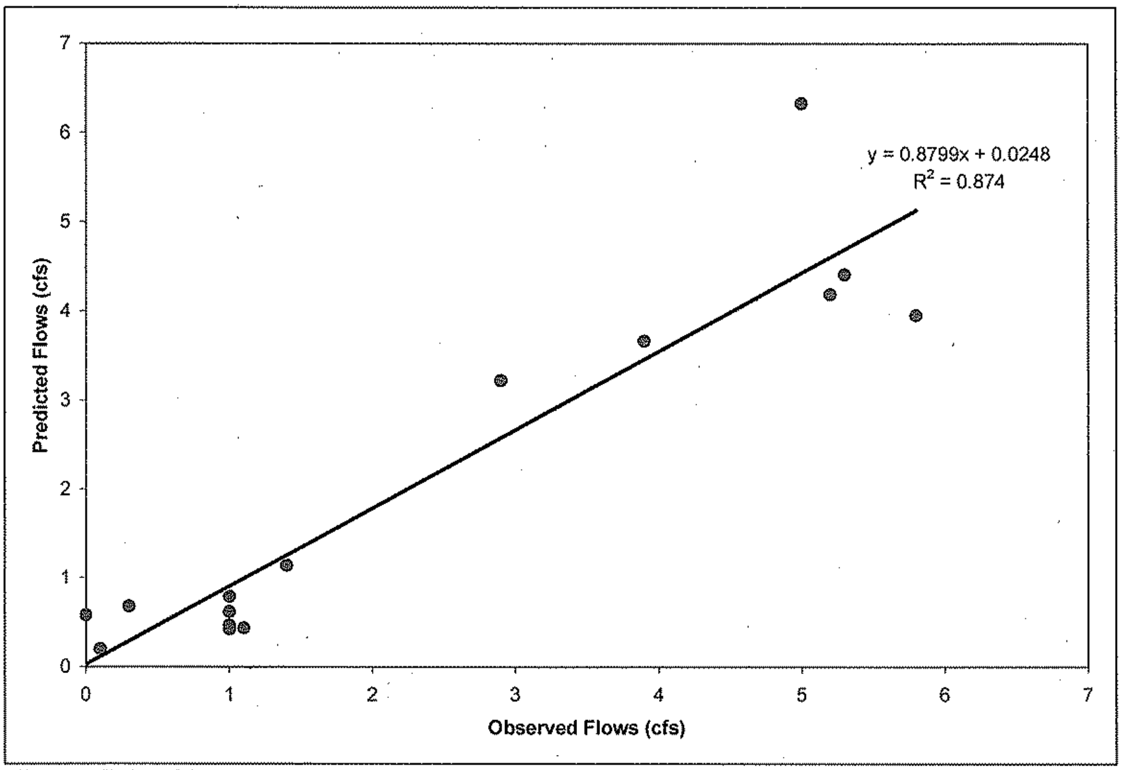


Figure D1. Observed versus predicted flows at the upstream monitoring site.

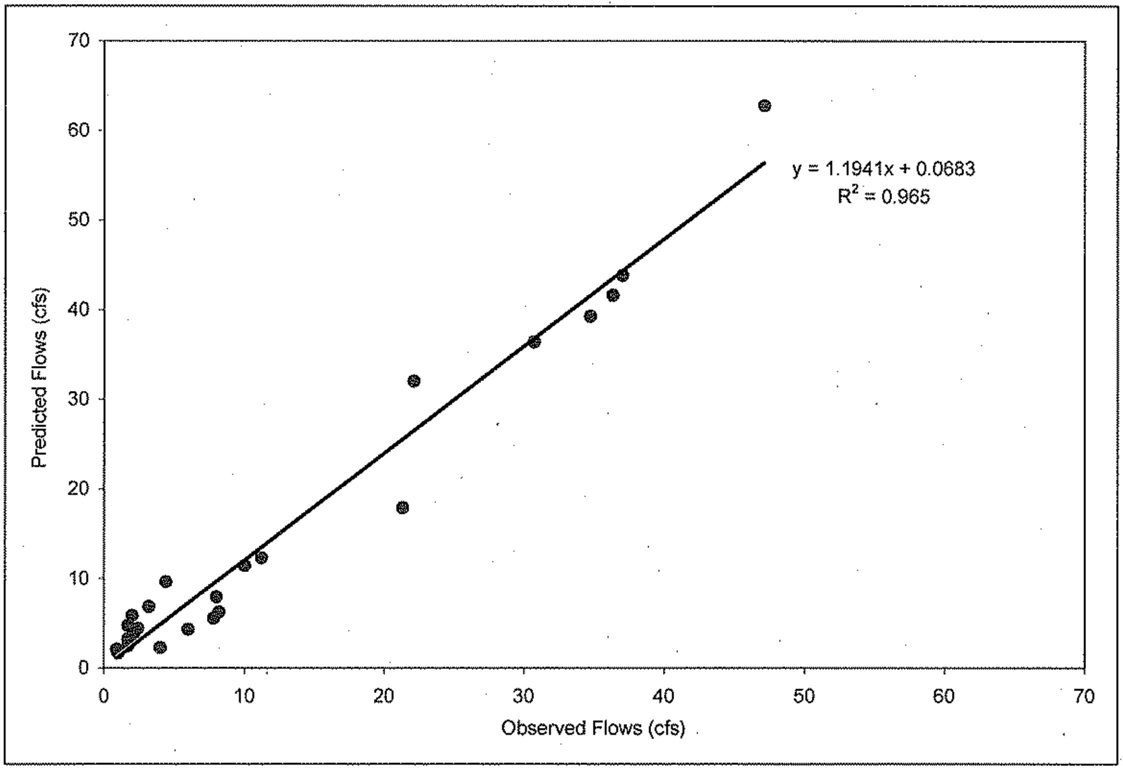


Figure D2. Observed versus predicted flows at the downstream monitoring site.

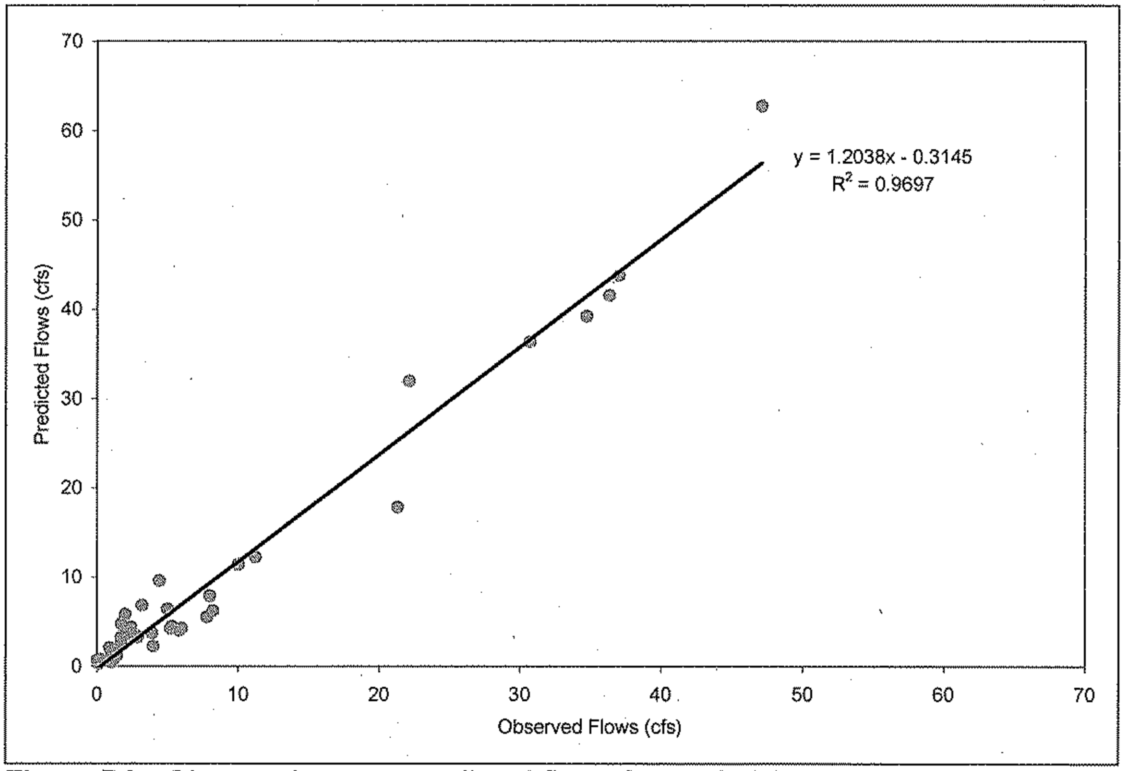


Figure D3. Observed versus predicted flows for pooled (upstream and downstream) data.

Estimation of sediment delivery from nonpoint sources

Field erosion of sediment was estimated using the Revised Universal Soil Loss (RUSLE) equation as described by Renard, 1991. Slope length, slope steepness, and soil erodibility factors (L, S, and K) were derived from county-level NRCS soil surveys. Crop/cover factors and management practice factors (C and P) were assigned to individual common land unit field boundaries based on observed land use and management noted during a windshield survey in the watershed done in 2003. Local NRCS personnel provided C and P factors according to the land use categories provided. For the estimation of long-term sediment erosion in the watershed, management practice factors (P factor) were set to 1 (no conservation practices) to portray the historic conditions. Then, P factors were taken into account to estimate the more recent incorporation of conservation practices on the landscape as an estimate of current conditions, as discussed in the implementation plan of this report.

To estimate sediment delivery to the stream, a delivery ratio of 11.21% was applied to all field soil erosion estimates in the watershed. The sediment delivery ratio, which estimates the fraction of field erosion actually reaching the stream, is based on watershed size and landform region and was estimated using the Iowa NRCS Erosion and Sediment Delivery protocol. The total watershed sediment delivery, 6,145 tons/yr, represents the average amount delivered to the watershed outlet on a long term annual basis.

Specific yearly loadings were estimated by temporally-weighting the long term average sediment delivery by total annual rainfall. The ratio of a specific year's total rainfall to the long term average annual rainfall (32.3") was multiplied by 6,145 tons/year to get a rainfall-adjusted delivery estimate. Subsequently, daily sediment delivery was estimated by taking the ratio of rainfall on a given day to that year's rain total and multiplying it times the yearly-adjusted sediment delivery. Weather data was obtained from the Iowa Environmental Mesonet (IEM, 2007).

No major areas of severe streambank erosion or gullies were identified during the 2003 windshield survey, and a follow-up visit to the watershed in May 2007 confirmed this. Although there are several reaches of the stream with continuously grazed streamside pasture, including direct cattle access, the contribution of streambank erosion to overall sediment loads is not severe. The channel appears to be fairly stable throughout most reaches of the watershed.

Linkage of phosphorus to excessive algae growth, increased stream metabolism, and reduced aquatic health

Figure 8 in Chapter 4 showed the correlation between plant-available phosphorus and periphyton chlorophyll-a in the stream. Figure D4 shows a similar relationship for total phosphorus and chlorophyll-a suspended in the water column for two biologically impaired streams in the Iowan Surface Ecoregion, Middle Fork South Beaver Creek and the North Fork Maquoketa River. Both streams experience similar nightly dissolved oxygen sags due to excessive plant respiration, with the North Fork Maquoketa River dataset being used to support statistical analyses of this type of impairment.

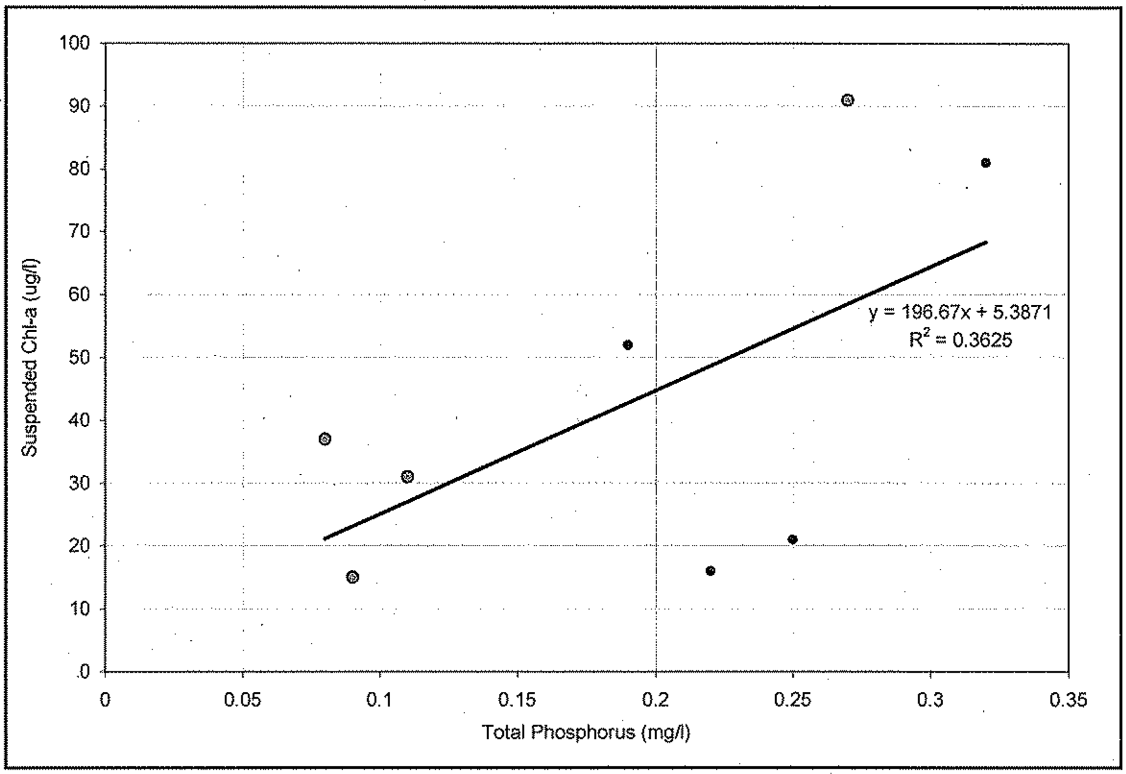


Figure D4. Relationship between TP and suspended chlorophyll-a in two impaired Iowan Surface streams. Large circles represent data from Middle Fork S. Beaver Creek.

Figure D5 provides evidence that nitrogen is not contributing to and/or controlling aquatic vegetation growth in Middle Fork South Beaver Creek as phosphorus is. Table D1 shows the ratio of total nitrogen to total phosphorus measured in Middle Fork South Beaver Creek during 2001 and 2003, which generally indicate that phosphorus, not nitrogen, is the limiting nutrient throughout most of the growing season (Sharpley et al., 1994). There are times, however, when phosphorus at the upstream site is so abundant that other factors (nitrogen or micronutrients, light, temperature) may temporarily limit algal growth.

Since Iowa does not have numeric standards for phosphorus, multiple approaches were used to select an appropriate Phase 1 target. Table D2 summarizes six alternative approaches to identifying a total phosphorus target that would reduce algal growth for Phase 1 of this TMDL. The methodology of each of these approaches is described next.

The first and second approaches were to consider regional nutrient criteria recommendations from the federal government. U.S. EPA guidance recommends a maximum concentration of 0.08 mg/l total phosphorus to control algal growth in streams and rivers of the Corn Belt and Northern Great Plains Ecoregion (Ecoregion VI) (USEPA, 2000). At a more refined geographical scale, (i.e. the Western Corn Belt Plains Ecoregion (Level III)) the recommendation for total phosphorus is relaxed to 0.12 mg/l.

However, this guidance strongly suggests that states refine nutrient criteria according to local conditions, as these criteria represent broad, general starting points for states to use in setting water quality standards (USEPA, 2000).

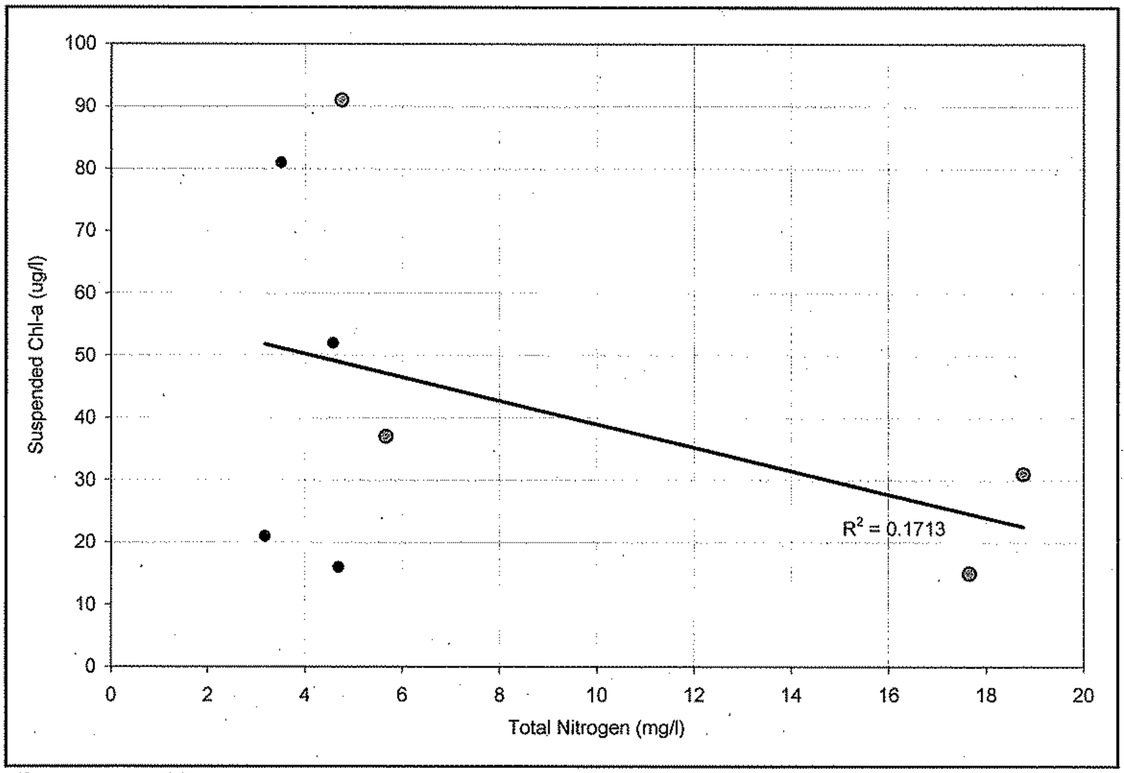


Figure D5. Negative correlation of TN to suspended chlorophyll-a for two impaired Iowan Surface streams. Large circles represent data from Middle Fork S. Beaver Creek.

The third approach was an investigation of ecoregion reference streams for IDNR bioassessment to see how phosphorus concentrations correlated with BMIBI scores. In reference streams of the Iowan Surface Ecoregion, there is a significant, though not strong, correlation between median total phosphorus concentrations and BMIBI scores (correlation = -0.36, p=0.01) (Figure D6). If a BMIBI target of 59 (impairment threshold) is desired, this statistical relationship would suggest a total phosphorus target of 0.19 mg/l.

Another approach to setting the Phase 1 phosphorus target (methods 4 and 5) consisted of analyzing relationships between phosphorus concentrations, algal growth, and stream metabolism. Stream metabolism refers to the collective productivity of aquatic plants in the ecosystem, characterized by gross primary productivity, net primary productivity, community respiration, and daily amplitudes of dissolved oxygen. These metrics are quantified using continuous dissolved oxygen monitoring data in a worksheet developed by Anderson and Huggins (2002).

Table D1. Ratios of total nitrogen to total phosphorus in 2001 and 2003.

Date	Sample Location	TN (mg/l)	TP (mg/l)	TN:TP
3/6/2001	Upstream	12.7	0.4	32
3/6/2001	Downstream	12.8	0.6	21
4/5/2001	Upstream	15.7	0.1	157
4/5/2001	Downstream	16.3	0.2	82
5/10/2001	Upstream	21.1	0.1	211
5/10/2001	Downstream	19.5	0.1	195
6/7/2001	Upstream	23.9	0.6	40
6/7/2001	Downstream	21.1	0.1	211
7/5/2001	Upstream	23.5	0.1	235
7/5/2001	Downstream	18.4	0.1	184
8/2/2001	Upstream	3.6	0.2	18
8/2/2001	Downstream	6.4	0.3	21
9/14/2001	Upstream	3.4	0.36	9
9/14/2001	Downstream	11.1	0.1	111
10/8/2001	Upstream	12.69	0.11	115
10/8/2001	Downstream	10.11	0.11	92
11/1/2001	Upstream	9.75	0.09	108
11/1/2001	Downstream	11.87	0.15	79
3/19/2003	Upstream	6.3	0.2	32
3/19/2003	Downstream	7.6	0.28	27
4/1/2003	Upstream	9.68	0.12	81
4/1/2003	Downstream	10.3	0.25	41
5/15/2003	Upstream	18.52	0.07	265
5/15/2003	Downstream	17.68	0.15	118
6/12/2003	Upstream	19.42	0.02	971
6/12/2003	Downstream	19.55	0.13	150
7/16/2003	Upstream	13.3	0.03	443
7/16/2003	Downstream	17.55	0.12	146
8/13/2003	Upstream	1.2	0.24	5
8/13/2003	Downstream	5.61	0.08	70
9/10/2003	Upstream	16.1	2.3	7
9/10/2003	Downstream	4.19	0.1	42
10/13/2003	Upstream	2.7	0.82	3
10/13/2003	Downstream	7.24	0.11	66

Table D2. Summary of alternative methods used to set total phosphorus target.

Number	Method	TP Target (mg/l)	Information
1	EPA criteria for Ecoregion VI	0.08	Developed for Cornbelt and Northern Great Plains Ecoregions (Level VI) (EPA, 2000)
2	EPA criteria for Level III Ecoregion	0.12	More refined to Western Cornbelt Plains Ecoregion (Level III) (EPA, 2000)
3	Reference stream BMIBI vs. TP regression	0.19	Simple regression model for Iowan Surface Ecoregion (r^2=0.12)
4	TP vs. Chl-a vs. GPP regression	0.08	Linked simple regression models for target gross primary productivity (r^2=0.36 and 0.92)
5	TP vs. Chl-a vs. ΔO_2	0.19	Linked simple regression models for target dissolved oxygen amplitude (r^2=0.36 and 0.94)
6	Qual2K modeling	0.12	Mechanistic modeling based on low-flow conditions, but limited by data
	Median value	**0.12**	

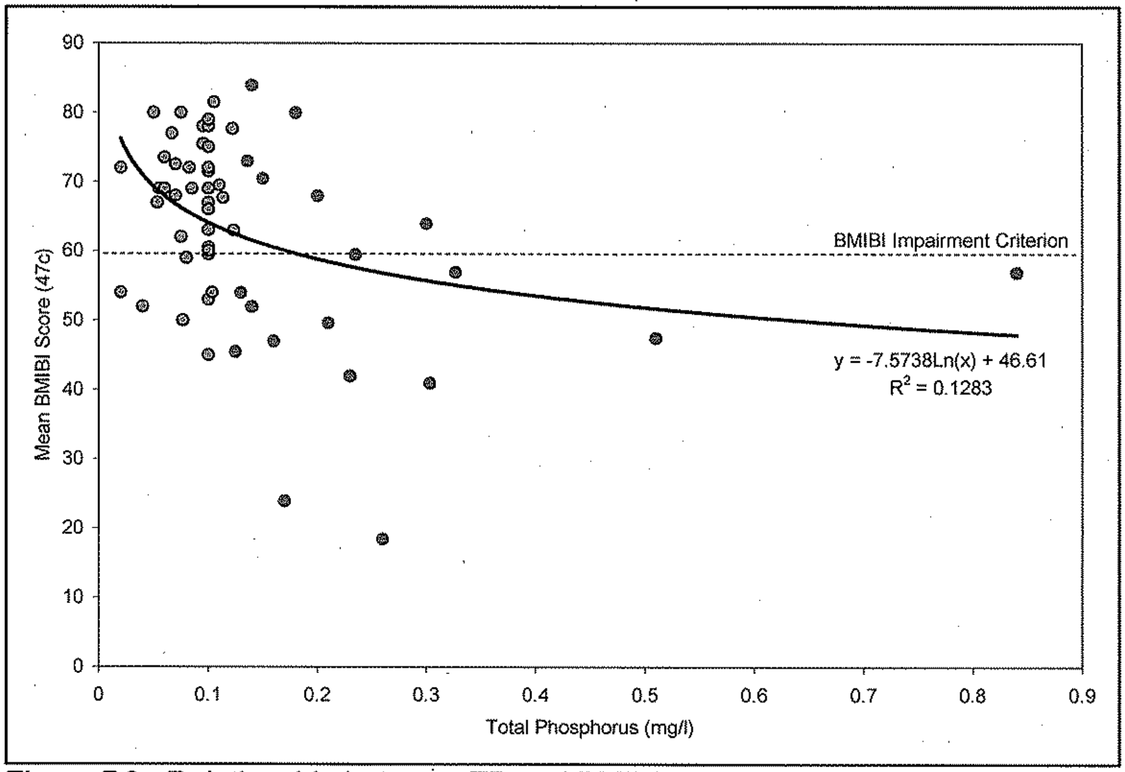


Figure D6. Relationship between TP and BMIBI scores in Iowan Surface reference streams. Gray dots represent streams with median TP ≤ 0.12 mg/l.

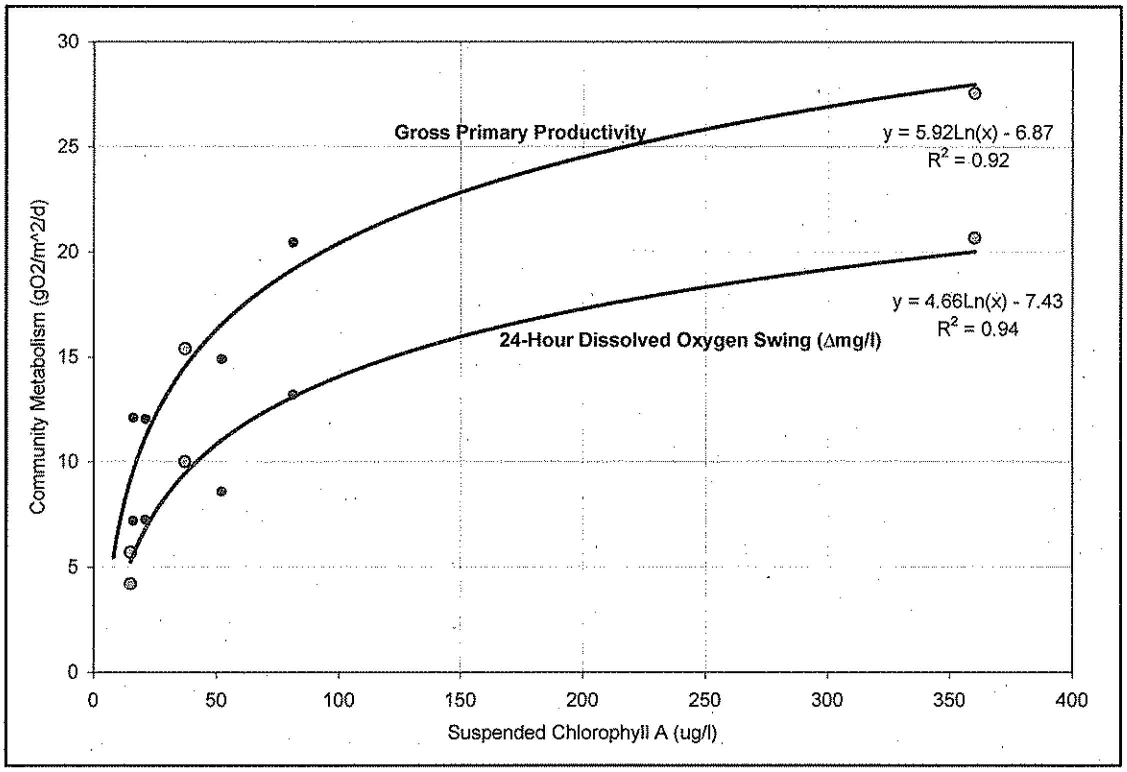


Figure D7. Relationships between stream metabolism and chlorophyll-a in two impaired Iowan Surface streams. Large dots represent data points from Middle Fork S. Beaver Creek.

Figure D7 shows the relationships between water column chlorophyll-a and two quantitative metrics for stream metabolism: average community gross primary productivity and 24-hour fluctuations between minimum and maximum dissolved oxygen (daily amplitude). In the Iowan Surface Ecoregion, there is evidence that suggests reduced biological index scores occur when average community gross primary productivity is greater than 11 gO_2/m^2/day and daily dissolved oxygen swings are greater than 10 mg/l (IDNR, 2006). Using these targets in the regression equations shown in Figure D7, target chlorophyll-a concentrations are calculated to be:

For gross primary productivity, where target productivity (y) = 11 gO_2/m^2/d:
$y = 5.92Ln(x) - 6.87$
$x = 20.7$ ug/l chlorophyll-a

For daily dissolved oxygen swings, where target amplitude (y) = 10 gO_2/m^2/d:
$y = 4.66Ln(x) - 7.43$
$x = 42.1$ ug/l chlorophyll-a

These chlorophyll-a targets were then used to calculate a total phosphorus target based on the relationship established in Figure D4:

For gross primary productivity, target chlorophyll-a (y) = 20.7 ug/l:

$y= 196.67x + 5.39$

$x = 0.08$ mg/l total phosphorus

For daily dissolved oxygen swings, target chlorophyll-a (y) = 42.1 ug/l:

$y= 196.67x + 5.39$

$x = 0.19$

Finally, mechanistic modeling was done using the Qual2K Stream Water Quality Model to determine what concentration of total phosphorus is needed to achieve stream metabolism and minimum dissolved oxygen targets in Middle Fork South Beaver Creek. Qual2K predicts a variety of physical, chemical, and biological parameters both longitudinally (downstream) and diurnally throughout a single 24-hour period.

Calibration of the model was done for August 14, 2003 according to the occurrence of critical conditions and the availability of monitoring data for that day. Physical stream attributes (e.g. channel width, depth, slope, etc.) were entered based on field and aerial photograph measurements, and chemical water quality sampling collected at Site 47 was used as input for headwater boundary conditions. Sample data collected downstream at Site 45 were then used to calibrate (adjust) parameters of the model to achieve the best results. Table D3 lists the model parameters that were adjusted during the calibration process.

Table D3. Calibration parameters for Qual2K modeling.

Q2K Sheet	Parameter	Default Value	Calibrated Value
Rates	Oxygen reaeration model	O'Connor-Dobbins	USGS Pool-Riffle
Rates	Bottom algae growth model	Zero order	First order
Rates	Bottom algae 1st order carrying capacity	1000	800
Rates	Bottom algae respiration rate	0.1	0.2
Light & Heat	Atmospheric attenuation model for solar	Bras	Ryan-Stolzenbach
Light & Heat	Atmospheric transmission coefficient	0.8	0.7
Light & Heat	Wind speed function for evaporation & air convection/conduction	Brady-Graves-Geyer	Adams 1

Figures D8 and D9 show the longitudinal streamflow calibration from Q2K (correlation coefficient = 0.99, p = 0.000). Figures D10 and D11 show calibration results for diurnal temperature modeling versus observed data collected at the downstream monitoring site (Site 45) (correlation = 0.98, p = 0.000). Figures D12 and D13 show calibration results for diurnal dissolved oxygen in Middle Fork South Beaver Creek (correlation = 0.97, p = 0.000).

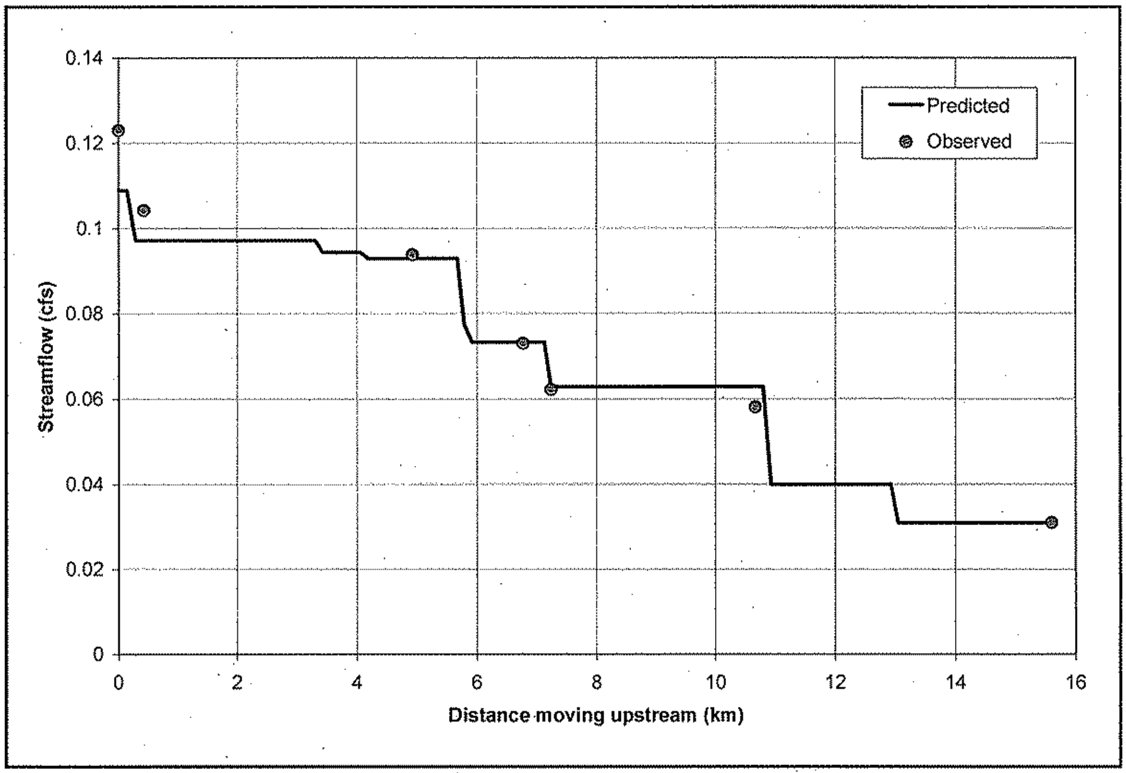


Figure D8. Longitudinal streamflow modeling for August 14, 2003.

When a reasonable calibration had been achieved, total phosphorus inputs from the headwaters, Ackley WWTP, and from small tributaries were reduced iteratively until daily dissolved oxygen swings were less than 10 mg/l, community gross primary productivity was less than 11 $gO_2/m^2/d$, and community respiration was less than 7.5 $gO_2/m^2/d$. This occurred when maximum stream total phosphorus concentrations were reduced to 0.12 mg/l.

As Table D2 previously showed, all six of the methods produced a total phosphorus target in the range of 0.08 to 0.19 mg/l. Among the six different methods, none have significantly higher or greater levels of confidence than any of the others; therefore, the median value (0.12 mg/l) was selected as an appropriate Phase 1 total phosphorus target for this TMDL. Analysis of Iowan Surface Ecoregion BMIBI scores from reference streams shows the probability of meeting the BMIBI target of 59 is 85% for streams with median TP levels of 0.12 mg/l or less. Thus, this target represents the sample median TP concentration, not a "never to exceed" value.

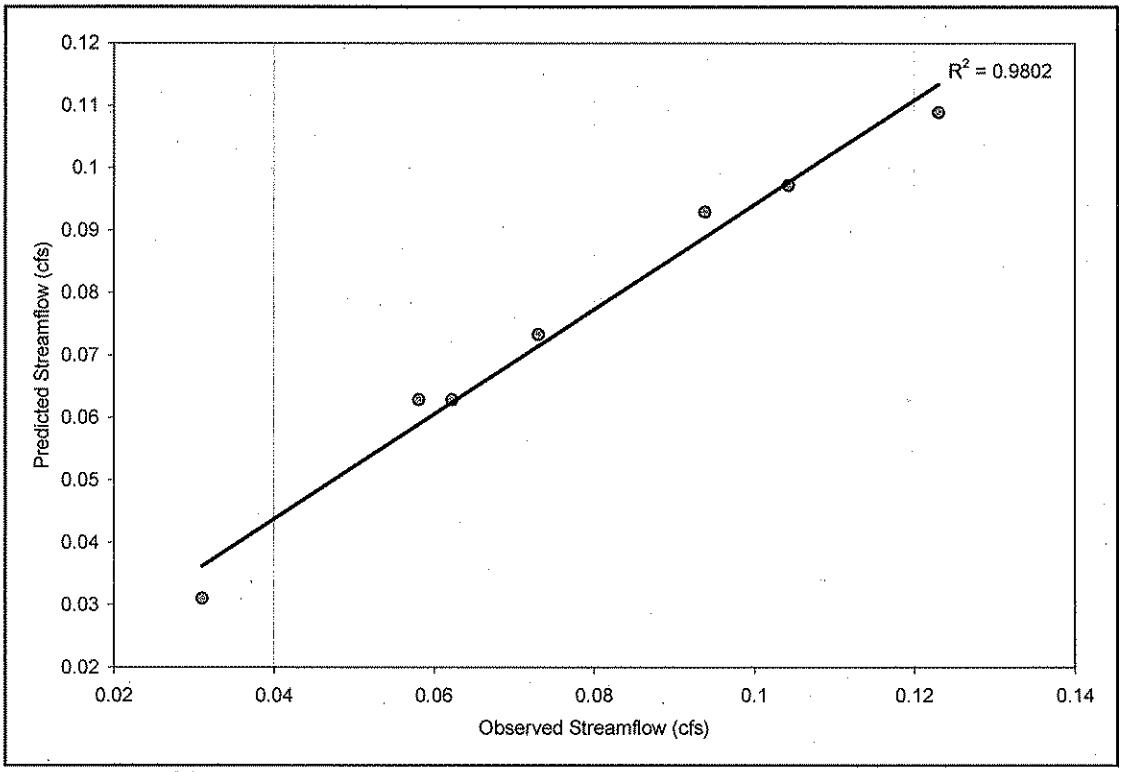


Figure D9. Observed vs. predicted streamflow values.

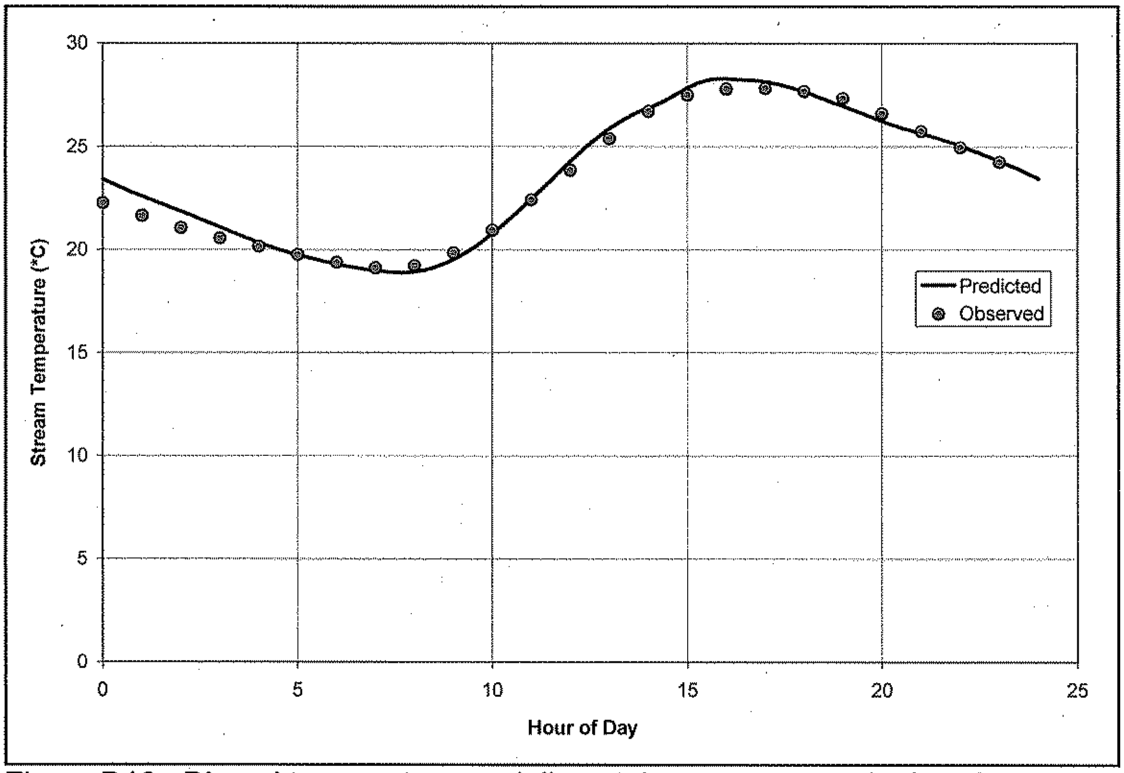


Figure D10. Diurnal temperature modeling at downstream monitoring site.

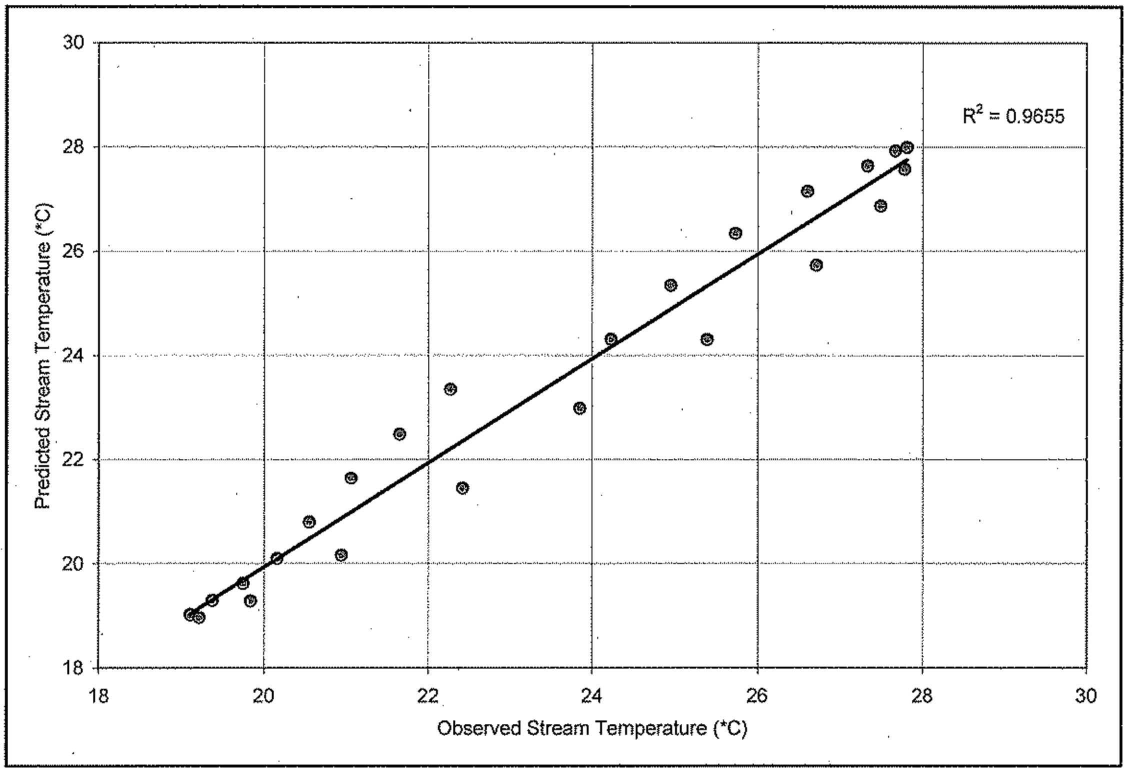


Figure D11. Observed vs. predicted temperature values.

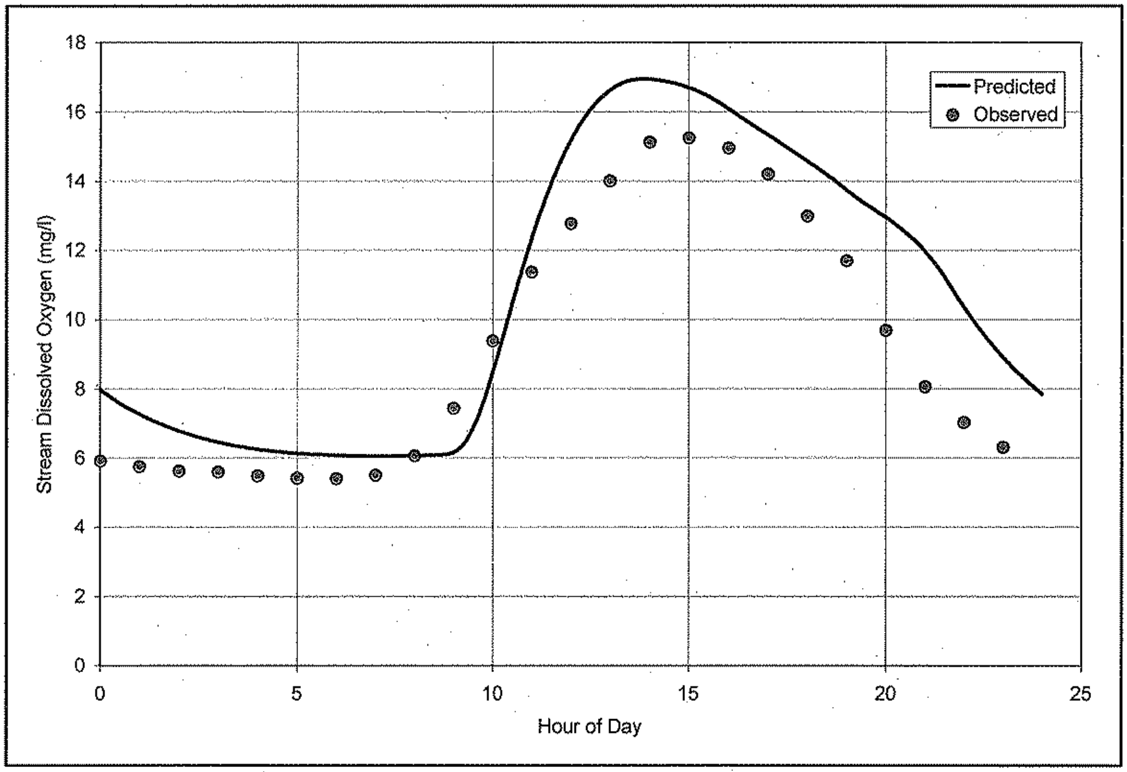


Figure D12. Diurnal dissolved oxygen modeling at downstream site.

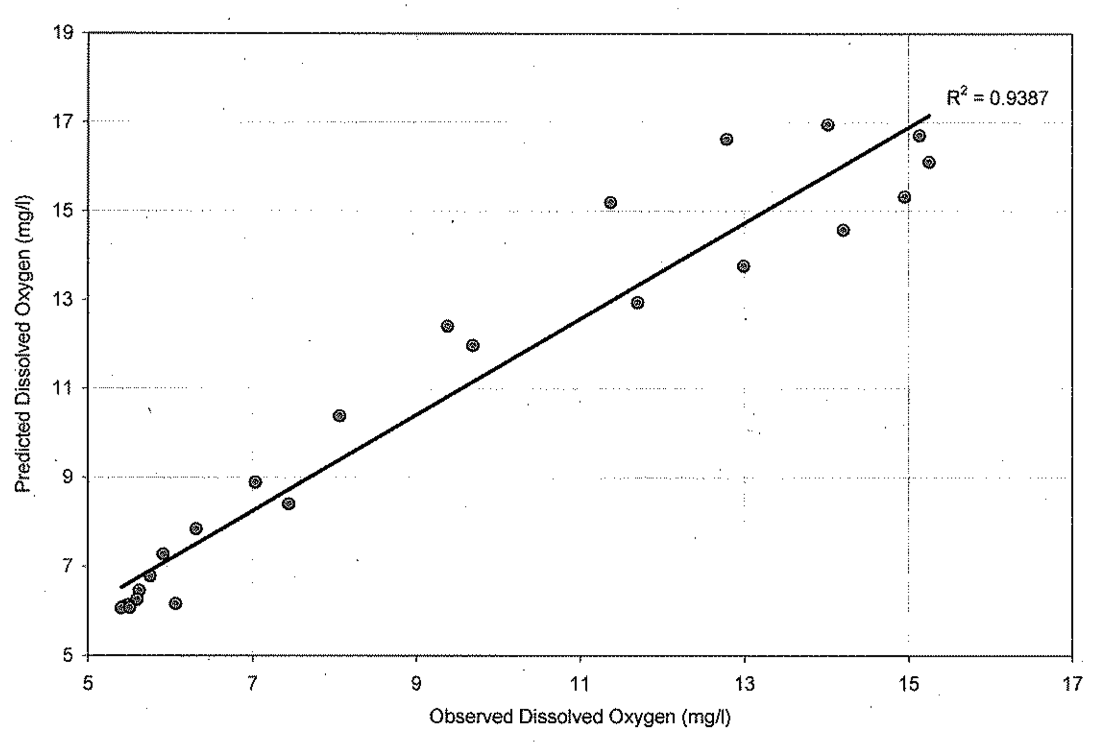


Figure D13. Observed vs. predicted dissolved oxygen values.

Estimation of total phosphorus loading from nonpoint sources, point sources, and background sources

Sources of phosphorus were categorized by delivery function/transport routes by which the nutrient reaches the stream. These include the following, in no particular order:

- Sediment-attached phosphorus delivered via sediment delivery
- Dissolved phosphorus transported by surface runoff and tile drainage
- Failing/illicit septic systems
- Direct deposition by livestock in the stream
- Point source discharges
- Direct atmospheric deposition

Methods of estimating nonpoint source phosphorus loading were based on procedures in EUTROMOD's loading function (Reckhow, 1992). For sediment-attached and dissolved phosphorus loading to Middle Fork South Beaver Creek, methods are comparable to those utilized for the Iowa Phosphorus Index (Mallarino et al., 2005). Sediment-attached loads were estimated based on annual sediment delivery to the stream from various land use categories multiplied by typical soil phosphorus contents and a standard enrichment ratio of 1.3, adjusted for units. Dissolved phosphorus loads were estimated by multiplying typical runoff concentrations for different land cover types by annual surface runoff/tile flow quantities and a multiplier for unit conversion. Table D4 lists the runoff coefficients, runoff dissolved phosphorus concentrations, and soil phosphorus contents used to estimate nonpoint source phosphorus loading.

Sediment-attached phosphorus: 6,145 tons/year sediment delivery (RUSLE delivery) x soil phosphorus content (mg/kg) x 1.3 enrichment ratio x 0.002 lbs/mg = **9,162 lbs/year sediment-attached TP**

Dissolved phosphorus: Annual runoff volume (ac-ft./yr) x typical runoff dissolved TP concentration (mg/l) x 2.72 = **13,667 lbs/year TP dissolved in runoff**

Total event-driven nonpoint source phosphorus loads = 22,829 lbs/year

Table D4. Parameters used in EUTROMOD loading function.

2003 Land Cover	Annual surface runoff coefficient (%)	Dissolved runoff TP concentration (mg/l)	Soil P concentration (mg/kg)
Other Conservation Rowcrop	26%	0.26	575
CAFO	29%	0.20	500
CRP-Grass	23%	0.10	500
Cemetary	23%	0.20	500
Corn-Beans-Conventional	25%	0.26	575
Corn-Beans-Mulch	26%	0.26	575
Corn-Beans-No Till	27%	0.26	575
Corn-Corn-Mulch	28%	0.26	575
Farmstead	29%	0.38	500
Farmstead-Abandoned	29%	0.38	500
Feedlot	60%	5.10	575
Forest/Tree	15%	0.01	500
Grassed Waterway	23%	0.10	500
Hayland	23%	0.15	500
Lagoon	100%	0.00	0
Natural Area	15%	0.01	500
Pasture	25%	0.25	500
Pond	100%	0.00	500
Quarry	20%	0.10	0
Railroad	60%	0.12	500
Railroad-Abandoned	60%	0.12	500
Road	86%	0.12	500
Salvage Yard	61%	0.20	500
Urban/Commercial	61%	0.38	500

Loading from illicit/failing septic tanks was estimated by determining the number of rural households with septic tanks, the number of people served per household, the failure rate of septic systems, and typical phosphorus content of untreated human wastewater (Tchobanoglous and Burton, 1991; Reckhow and Chapra, 1983). U.S. Census data from 2000 was used to estimate the number of housing units served by septics (area-weighted from county-level census data) and the average rural household size, while local county sanitarians were contacted for failure rates.

Grundy County: 5,304 rural housing units (2000 U.S. Census) x 91% occupancy rate x 6.4% of Grundy County encompassed by watershed = 308 housing units served by septics in Grundy County portion of watershed

308 households x 2.45 people/home (2000 U.S. Census) x 1.76 lbs/capita/year TP x 90% septic failure rate (worst-case) (Misty Wells, Grundy County Sanitarian, 2/20/2007, personal communication) = 1,195 lbs/year TP from septics

Hardin County: 24 rural households in watershed (from 2002 aerial photography) x 91% occupancy rate (2000 U.S. Census) x 2.35 people/home x 90% failure rate = 82 lbs/year TP from septics

Total Septic Loading = 1,277 lbs per year or 3.5 lbs/day

To estimate loading from livestock with direct access to streams, pastures that were located along perennial streams were identified and the number of acres were calculated. The average number of cattle & calves per acre of pastureland was obtained at the county level from the 2002 U.S. Ag Census. This number was assumed to be evenly distributed across all pastured acres throughout both counties, thus, the number of head with access to streams could be quantified. Finally, typical phosphorus concentrations in cattle waste (Midwest Plan Service, 1985) were used to estimate daily loading along with assumptions as to the amount of time cows spend in the stream versus in the pasture during the growing season (IDNR, 2006).

Grundy County: 1.7 head/acre (2002 Ag Census) x 303 pastured acres w/ stream access x 0.19 lbs/day TP produced per head x 3.5% of day spent in stream = 3.42 lbs/day (April- December only)

Hardin County: 1.02 head/acre (2002 Ag Census) x 32 pastured acres w/ stream access x 0.19 lbs/day TP produced per head x 3.5% of day spent in stream = 0.217 lbs/day (April-December only)

Total Cattle in Stream Loading = 3.6 lbs/day (April through December) or 889 lbs/year

Estimates of the current contributions from point source discharges were made using discharge monitoring records from the Ackley wastewater treatment plant and assumed effluent concentrations for a typical aerated lagoon (Tchobanoglous and Burton, 1991).

Ackley WWTP: 0.319 MGD x 5 mg/l TP x 8.34 lb/gal = **13.3 lbs/day or 4,855 lbs/year total phosphorus loading from point sources**

Direct atmospheric deposition was estimated by determining the surface area of the stream and typical annual loading rates of TP in dryfall and wetfall (Anderson and Downing, 2006):

67.3 acres of stream surface area x 0.26 lbs TP/acre/year = **0.049 lbs/day or 17.5 lbs/year TP from atmospheric (natural) background sources**

Appendix E --- Additional Maps

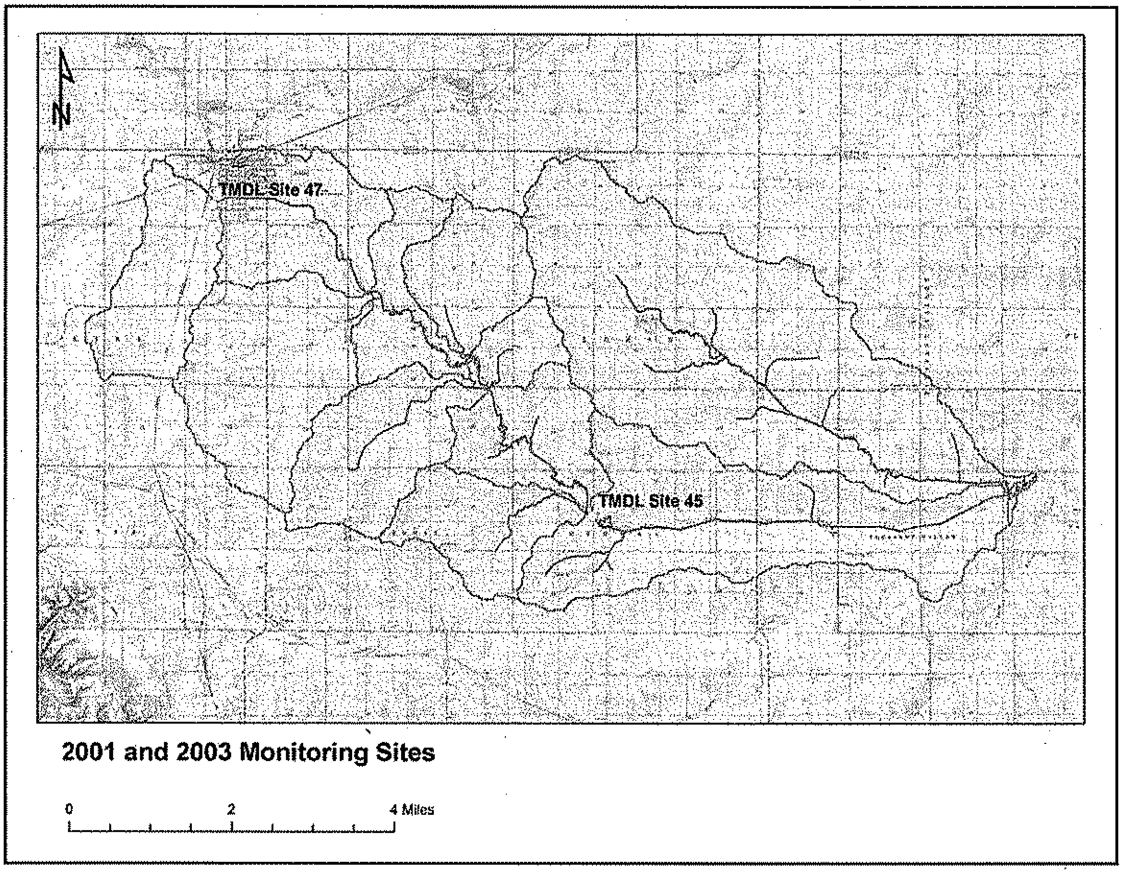


Figure E1. Location of 2001 and 2003 bioassessment and water quality monitoring sites.

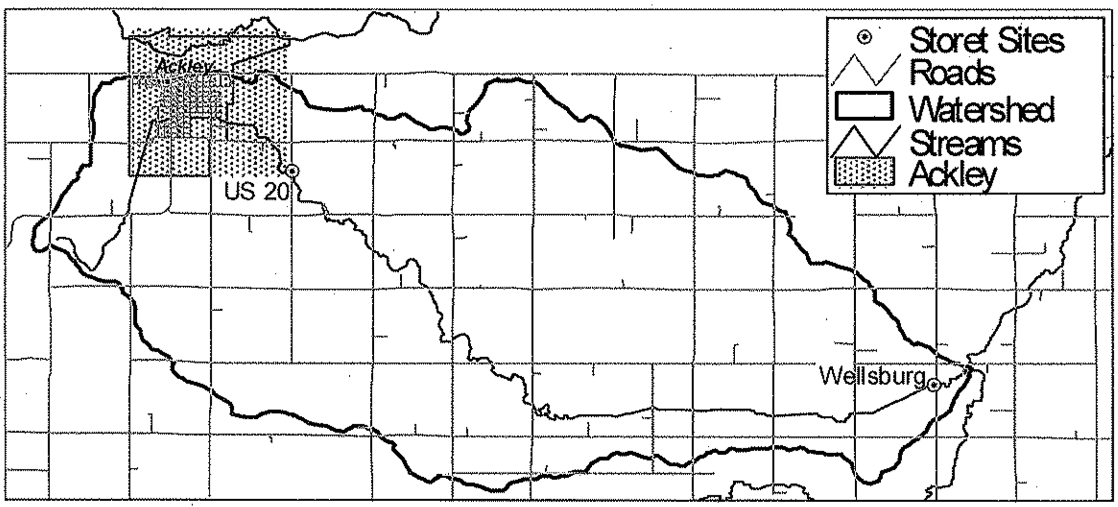


Figure E2. Legacy STORET monitoring sites for September 22, 1975.

Appendix F --- Public Comments

No written comments were received on the Draft TMDL.

Stressor Identification for Middle Fork South Beaver Creek

The goal of this stressor identification (SI) document is to determine the cause of the biological impairment on Middle Fork South Beaver Creek in Hardin and Grundy Counties. This waterbody is included on the 303(d) list of impaired waters and is scheduled for TMDL development in 2004.

Data available for Middle Fork South Beaver Creek includes two biological samples collected in 2001, water chemistry data from two locations in 2001 and 2003, data from auto samplers deployed in 2003, information from the City of Ackley STP, and data from the Legacy Storet system. The data were analyzed and the SI was completed by three members of the TMDL and Water Quality Assessment Section of the DNR. The SI follows steps A-G outlined in the IDNR (2004) procedures document, which was developed from U.S. EPA (2000) guidelines.

A. Describe the Impairment

1. What effect is observed?
The original indication of impairment was a series of four fish kills from 1991 to 1997. Kills in September 1991 and September 1997 were attributed caused by discharges from local industry. Kills in August 1994 and August 1995 were caused by silage runoff.

In two biological samples collected in 2001, Middle Fork South Beaver Creek had low scores in the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI). The Fish Index of Biotic Integrity (FIBI) scores were 65 (good) and 46 (fair). The associated BMIBI scores were 36 (fair) and 30 (poor).

2. How was the effect determined?
The scores above were compared to reference sites in the Iowan Surface ecoregion for the Mississippi drainage system. According to Table 1 of Attachment 2 in the "Methodology for developing Iowa's 2002 Section 303(d) list of Impaired Waters," BMIBI scores of 59 or higher are considered 'supporting' the aquatic life use. FIBI scores of 71 or higher in riffle habitat and 43 or higher in non-riffle habitat are classified as 'supporting.'

3. Where is the impairment?

a. Geographic (Spatial) Extent. The impairment is along 8.4 miles of Middle Fork South Beaver Creek in Hardin and Grundy Counties. The 15,100-acre watershed includes the town of Ackley (see Figure 1).
b. Temporality. The sample size is insufficient to quantify any seasonal or annual variation in the impairment.

c. Chronology. The impairment was first documented in a 1991 stream use assessment. The impairment was more quantitatively identified in 2001 with two full bioassessments.
d. Severity. The impairment is viewed as moderately severe. Spatially, the impairment is expected to span all 8.4 miles of the listed 'impaired' section of Middle Fork South Beaver Creek.
e. Evidence. The evidence of impairment includes multiple samples, collected at multiple sites, using multiple indicators. Indices are used to compare Middle Fork South Beaver Creek samples to regionally appropriate data by the use of ecoregions and stream reference sites.
f. Confidence. Because the sampling locations were distributed along the 'impaired' stretch of Middle Fork South Beaver Creek, we are fairly confident that the impairment is represented throughout the listed segment. There may be a gradient to the impairment, with greater impairment nearer to the headwaters and/or Ackley.

B. List Possible Causes

1. List ALL possible stressors for the waterbody

Table 1 lists the possible causes of impairment that were identified by the SI team of investigators. GIS maps depicting natural and anthropogenic features of the Middle Fork South Beaver Creek watershed were examined. The presence or absence of potential sources of pollution or habitat alteration were noted. A master list of impairment causes and sources based on the Section 305(b) assessment methodology was reviewed to ensure that all possible causes and sources were initially considered. A numeric rating was then assigned to each potential cause.

Figure 1. Middle Fork South Beaver Creek watershed.

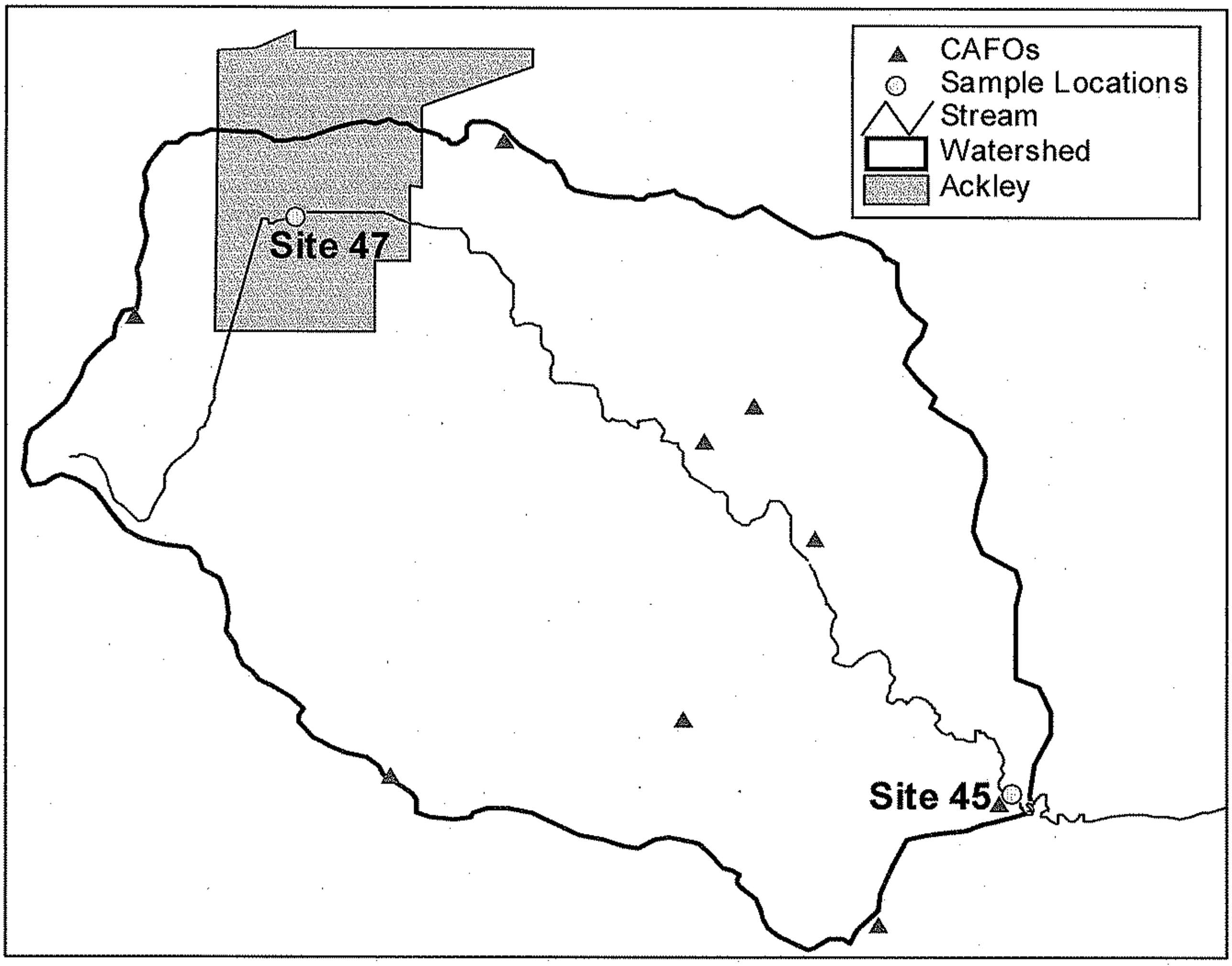


Table 1. Potential stressors in Middle Fork South Beaver Creek. A rating of 1 signifies high potential impact, 2 signifies moderate potential impact and 3 signifies low potential impact.

Possible Causes	Rating
• Physical and Chemical Traits of Water ○ Dissolved oxygen ○ Chlorophyll a	1
• Habitat Alterations ○ Siltation ○ Channelization ○ Algal growth	1
• Nutrients ○ Phosphorus ○ Nitrogen ▪ Nitrate ▪ Nitrite ▪ Total ammonia ▪ Kjeldahl nitrogen	1
• Toxins ○ Metals ▪ Arsenic ▪ Cadmium ▪ Chromium ▪ Copper ▪ Lead ▪ Selenium ▪ Zinc ▪ Other metal toxin ○ Non-Metals ▪ Chlorine ▪ Cyanide ▪ Sulfur ▪ Unionized Ammonia ▪ Priority organics ▪ Non-priority organics ▪ Other non-metal toxin	2
• Physical and Chemical Traits of Water ○ Suspended solids ○ Turbidity ○ pH	2
• Habitat Alterations ○ Riparian vegetation loss ○ Stream dewatering	2
• Flow Alterations ○ Dams ○ Pumping ○ Tile flow	2
• Pesticides/Herbicides ○ Pesticides ▪ Atrazine ▪ Other ○ Herbicides	2
• Physical and Chemical Traits of Water ○ TDS ○ Salinity	3
• Habitat Alterations ○ Barriers to movement ○ Wetland loss	3
• Exotic/Introduced Species ○ Predation ○ Competition	3
• Other ○ Depletion ▪ Predation ▪ Harvest ▪ Disease ○ Oil/grease ○ Thermal Modification ○ Noxious aquatic plants	3

2. *Eliminate unlikely causes (document the reason for elimination)*

- Toxins
  - Metals
    - Mercury – Not particularly toxic for macroinvertebrates.
- Other
  - Radiation – Not known to exist within the watershed.

C. Develop Conceptual Models

1. *Link the cause(s) with the effect*
2. *Draw a visual model of the pathway(s) or mechanism(s) (e.g., box-and-arrow)*
3. *Determine possible interactions between various causes*

Flow charts have been developed for potential habitat issues (Figure 2) and for potential water quality sources (Figure 3) in Middle Fork Southe Beaver Creek.

D. Analyze Evidence

Summaries of the data and evidence used for this SI may be found in the Appendices. Contact the TMDL and Water Quality Assessment Section for additional information on available data/evidence and how they were used. The analysis of evidence was largely conducted along with Cause Characterization (E1).

E. Characterize the Cause(s)

1. *Analyze strength of evidence.*

Table 2 lists the results of the causal evidence analysis. For each possible cause, a rating was assigned to each of the evidence categories in the table's leftmost column. The last evidence category (xii) is for any remarks pertaining to evidence coherence. The bottom row is a sum of the individual ratings. The higher the value for a particular stressor, the stronger the evidence that the stressor is a significant causal factor in the biological impairment.

Figure 2. Habitat Flow Chart

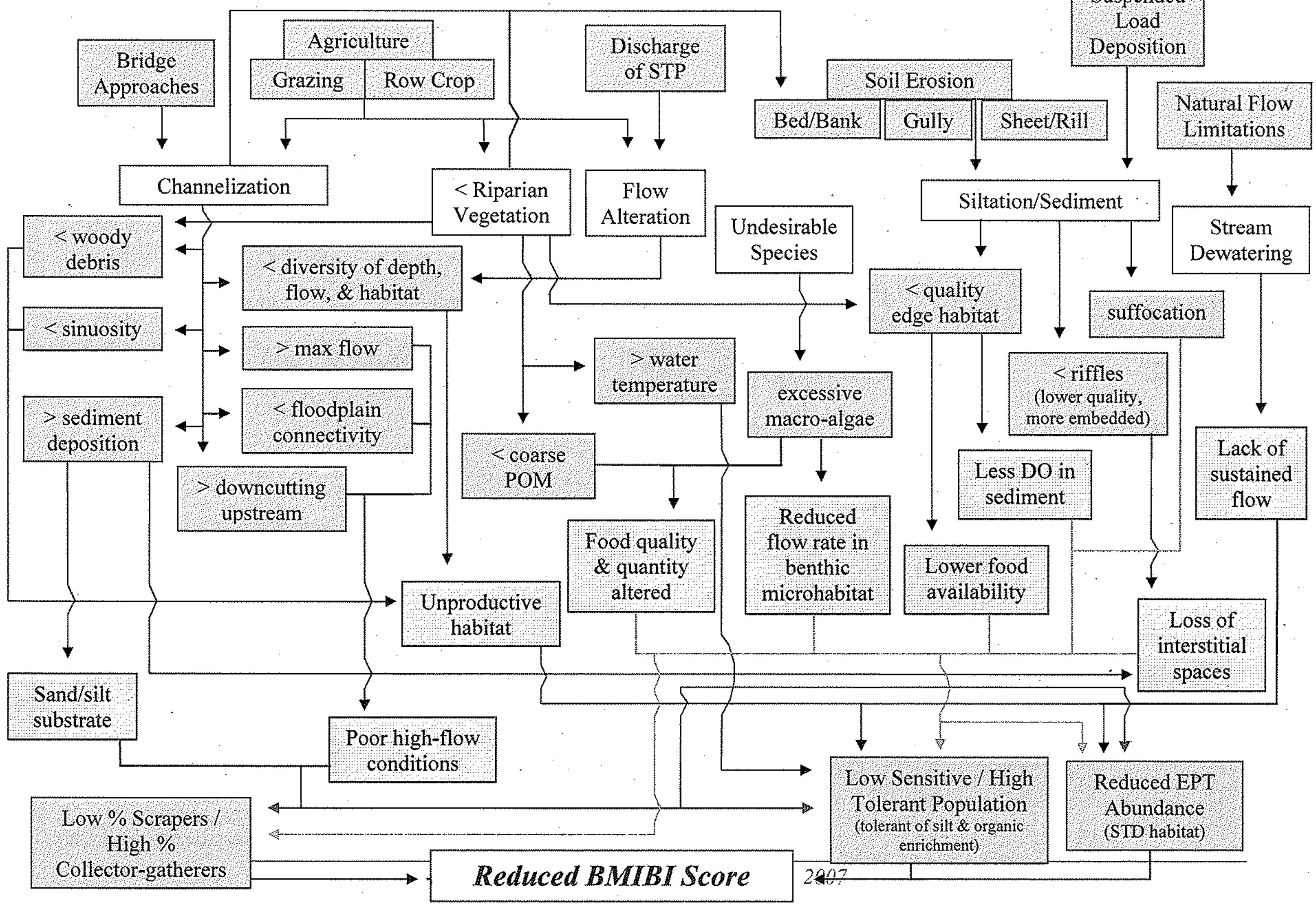


Figure 3. Water Quality Flow Chart

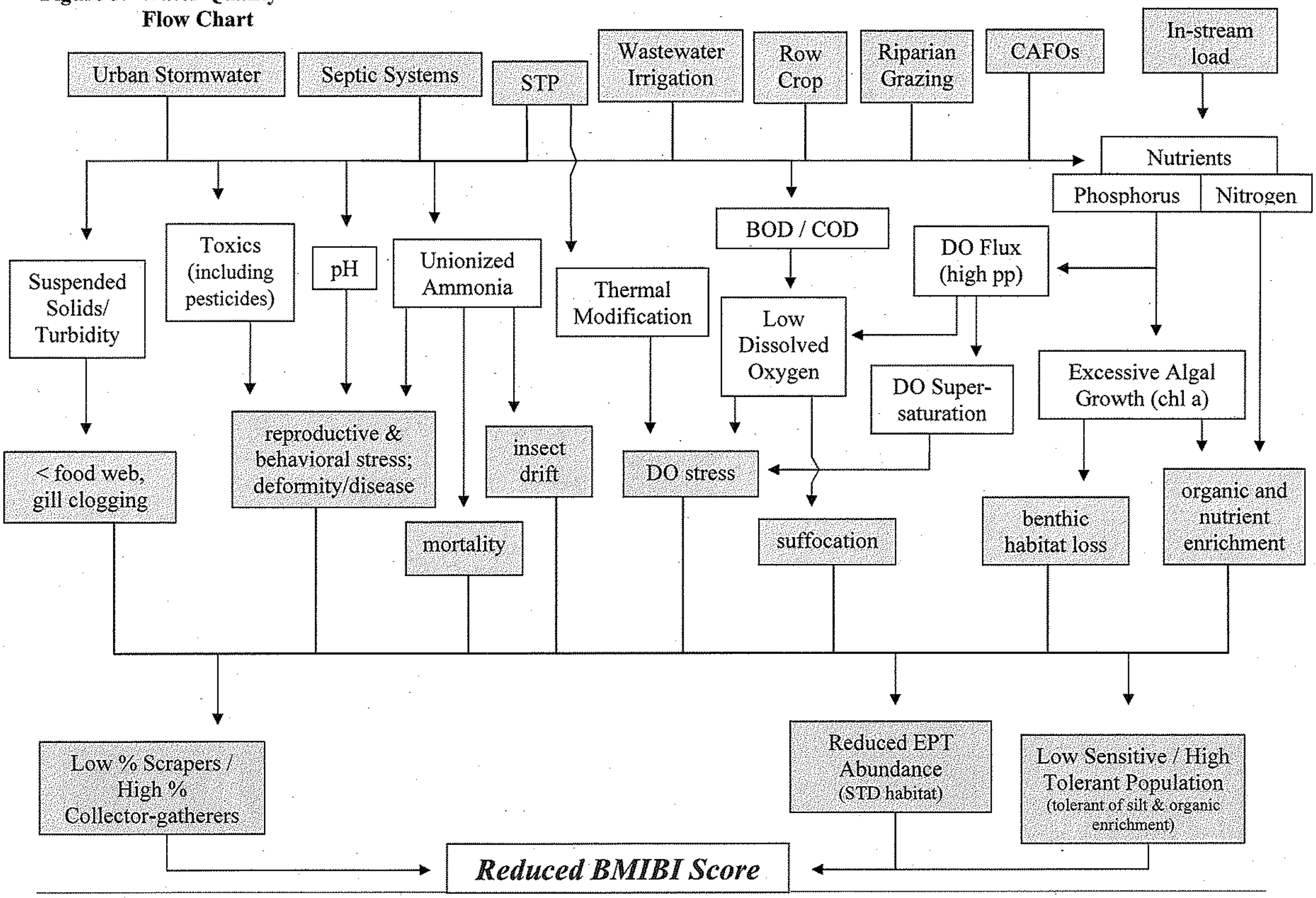


Table 2. Causal evidence analysis for Middle Fork South Beaver Creek.

	TSS/ Turbid	Toxins	DO	NH_3	pH	Nutrients		Algal Growth	De-watering	Silt/ Sediment	Channel-ization	<Riparian Veg.	Flow Alt.
						N	P						
i) co-occurrence	+	0	+	+	-	+	+	+	+	+	+	+	+
ii) temporality	0	0	0	0	0	0	0	0	0	0	0	0	0
iii) biological gradient	0	0	0	-	-	0	0	0	+	0	+	-	0
iv) exposure pathway	+	+	+	+	-	+	+	+	+	+	+	+	+
v) consistency of association	0	0	+	0	-	+	+	0	0	+	+	0	0
vi) experiment	0	0	0	0	0	0	0	0	0	0	0	0	0
vii) plausibility	0	0	+	0	-	+	+	+	+	+	0	0	0
viii) analogy	+	+	+	+	0	+	+	+	+	+	0	+	+
ix) specificity of cause	0	0	0	0	0	0	0	0	0	0	0	0	0
x) predictive performance	+	0	+	-	-	+	+	+	0	+	+	+	0
xi) evidence consistency	-	0	0	-	-	0	0	0	-	0	-	-	-
xii) evidence coherence													
Total	+3	+2	+6	0	-7	+6	+6	+5	+4	+6	+4	+2	+2

+ = evidence supports; 0 = no evidence to support or refute; - = evidence does not support

Evidence categories ii, vi and ix are rated as 0 for all possible causes. Evidence of temporality was unavailable due to a lack of biological samples over time. Evidence from experiments was unavailable due to a lack of experiments associated with the impairment. Evidence regarding specificity of cause was unavailable due to the general nature of the biological impairment.

2. Eliminate alternatives

Based on the strength of evidence chart above, we are eliminating TSS/turbidity, toxins, ammonia, pH, dewatering, channelization, loss of riparian vegetation, and flow alteration.

TSS

Monthly and event sampling in Middle Fork South Beaver Creek showed low TSS (below 40 mg/l) in most of the samples; however, there are a few episodes of high turbidity (up to 180 mg/l). More than half of the samples had TSS higher than the 75th percentile for ecoregion reference sites (15.75 mg/l). The most puzzling aspect of the TSS is that high TSS values are associated with low, medium, and high flow conditions. However, in the six months prior to the biological sampling, there were no instances of TSS over 50 mg/l and there were no high TSS measurements at site 45 (downstream) without an event. While there does appear to be an unusual regime of suspended solids in Middle Fork South Beaver Creek, the levels do not indicate a condition that would require immediate attention.

Toxins

No data regarding toxins in Middle Fork South Beaver Creek is available at this time. It is plausible that insecticides in the stream might impact the benthic macroinvertebrates, but without any evidence, this potential factor cannot be evaluated as a cause of impairment.

Ammonia

UHL samples show that ammonia levels in Middle Fork South Beaver Creek appear to spike each March, most likely a response to snowmelt events. There were also three violations of the permitted 30-day average mass discharge from the City of Ackley STP; however, effects of these high loads was not noted in the monthly UHL samples and so the effects of these loads is not expected to be significant enough to impair the aquatic life in the stream. This assessment is partly based on the fact that ammonia levels are higher more frequently at the downstream site where the benthic invertebrate community is not as severely impacted.

pH

UHL and City of Ackley STP data show no sign of pH outside the standard range. Therefore, this potential cause is not viewed as a source of impairment.

Stream Dewatering

There is evidence that flow in Middle Fork South Beaver Creek is very low in the upstream areas for much of the year; however, we do not have sufficient information to draw conclusions about the causes (natural vs. anthropogenic) or effects of stream dewatering. Although dewatering does seem to occur at the upstream site, it does not appear to be an issue at the downstream site. This is inconsistent with the BMIBI scores in the stream.

Channelization
Channelization in Middle Fork South Beaver Creek is viewed as moderate at the downstream site and severe at the upstream site. However, we could not come up with a scenario in which channelization would have such a dramatic effect on the benthic macroinvertebrates without also lowering FIBI scores. Therefore, channelization is not included as a source of impairment.

Lack of Riparian Vegetation
Riparian vegetation along Middle Fork South Beaver Creek is primarily herbaceous and is not contributing woody debris to the stream channel. It contributes a limited amount of shade and organic matter. While the impacts of the lack of riparian vegetation should be more intense at the downstream site, the fish community and the EPT taxa in the multi-habitat sampling do not reflect this kind of effect.

Flow Alteration
Several sources of flow alteration occur within the Middle Fork South Beaver Creek watershed; tile drainage, urban storm runoff, effluent of the City of Ackley STP, and a small rock dam located near the upstream sampling site were considered. Of these options, only the small rock dam appears to have the potential to cause significant negative changes to the aquatic habitat. While the dam may contribute to the potential dewatering effects at the upstream site, it would not influence the downstream site. It is also possible that the dam acts as a refuge for aquatic organisms during low flow/dewatering. Evidence is insufficient to include this as a cause of impairment.

F. Identify Probable Cause and Evaluate Confidence

1. *Describe the cause in as much detail as possible*
2. *Summarize the basis for the determination*
3. *Present any uncertainties*
4. *Determine confidence level*

Nutrients (N and P)
Excess nutrients, both nitrogen and phosphorus, in Middle Fork South Beaver Creek have led to reduced BMIBI scores. Nutrients in the stream allow for excessive algal growth which can cause pronounced daily swings in dissolved oxygen and nightly dissolved oxygen sags. In Middle Fork South Beaver Creek, these sags send dissolved oxygen levels below the 4 mg/l standard (IAC 2004) regularly during low flow periods. These levels of oxygen could be causing stress in the invertebrate community. Algal growth in the benthos can also limit the availability of habitat for benthic macroinvertebrates.

Nutrient levels were identified as a problem in the Middle Fork South Beaver Creek watershed based largely on samples collected by UHL (Appendix II). Nitrate concentrations were consistently above 15 mg/l in May, June, and July. Total Kjeldahl nitrogen was often above 1 mg/l in the spring and fall with event samples reaching 4.9 mg/l and non-event samples up to 16.0 mg/l. Total phosphorus concentrations at both sites generally followed the same pattern as TKN with higher values (0.2 mg/l and above) in the spring and fall and lower values in the summer. All event samples had high TKN and total phosphorus concentrations.

Nitrate levels during base flow were lower at the upstream site than at the downstream site. This is probably related to inputs form the City of Ackley STP.

We are confident that the data are sufficient and accurate, allowing us to conclude that high nutrient levels in Middle Fork South Beaver Creek contribute significantly to the problems of the biological community. We believe that there is strong enough evidence to justify action to reduce phosphorus and/or nitrogen levels in Middle Fork South Beaver Creek and that this action will have a positive impact on the biological community in the creek.

Dissolved Oxygen

Low levels of and extreme fluctuations in dissolved oxygen have led to reduced BMIBI scores. Iowa water quality standards for Class B(LR) streams state that the minimum level of dissolved oxygen in 4.0 mg/l and that levels must be at least 5.0 mg/l for 16 hours of every 24-hour period (IAC 2004). Although Middle Fork South Beaver Creek is currently only classified as a General Use stream, these standards were designed to allow the support of aquatic life. The low levels of dissolved oxygen found in Middle Fork South Beaver Creek could stress the invertebrate community.

Dissolved oxygen measurements taken at the downstream site over a two-week period by an auto sampler show that oxygen levels fluctuate widely over a 24-hour period with dissolved oxygen dipping below 5 mg/l each night for several hours at a time. Monthly grab samples collected by UHL show do not show low levels of dissolved oxygen at the downstream site, but do show low dissolved oxygen on several occasions at the upstream site.

At the upstream site, dissolved oxygen levels may cause an even less hospitable habitat. Dissolved oxygen in monthly UHL samples collected in 2001 and 2003 were below 2.5 mg/l on two occasions and below 5.0 mg/l on four occasions (Table 3). In these cases, the dissolved oxygen measurements were made in the morning. At this time of day, the sun has been up for short time, allowing photosynthetic activity to replenish a portion of the oxygen supply. These low values may indicate a dissolved oxygen flux such as that monitored in Middle Fork South Beaver Creek from 8/13/03 to 8/27/03 (Figure 5).

We are confident that low levels of dissolved oxygen are causing reductions in the biological community. The dramatic fluctuations in oxygen levels shown in Figure 5 have been documented in other cases and are considered a common phenomenon in streams under low flow conditions with nutrient loads that promote primary production.

Table 3. Low concentrations of dissolved oxygen measured by UHL at the upstream site on Middle Fork South Beaver Creek.

Date	Time	Dissolved Oxygen (mg/l)	Flow (CFS)
8/2/2001	9:00am	4.3	0
9/14/2001	10:00am	2.4	1
8/13/2003	10:15am	3.8	1.1
10/13/2003	9:45am	1.9	0.1

Algal Growth

Excessive macrophytes and algal growth have led to a reduction in the BMIBI scores in Middle Fork South Beaver Creek. Macrophytes and algae can cause pronounced daily swings in dissolved oxygen, including nightly dissolved oxygen sags. In Middle Fork South Beaver Creek, these sags send dissolved oxygen levels below 5 mg/l on a regular basis during low flow periods. In addition, algal growth in the benthos limits the availability of habitat for benthic macroinvertebrates. This is especially true of scraper organisms, which are replaced by collector filterers and gatherers in organically enriched conditions.

The relatively high level of chlorophyll in Middle Fork South Beaver Creek indicates algal growth. In the five samples collected, chlorophyll a concentrations (corrected for pheophytin) ranged from 13 to 320 ug/l in the water, 13 to 71 ug/cm^2 in the periphyton, and 2.1 to 50 ug/cm^2 in the sediment (Table 6). In addition, the photosynthetic activity and respiration of these organisms is evident in the extreme fluctuations of dissolved oxygen levels.

We are confident that excessive macrophytes and algal growth are a contributing factor in the reduced BMIBI scores found at Milford Creek. Direct physical observation, measured data, and predictive parameters all support this conclusion.

Silt/Sediment

Excessive silt and sediment deposition in Middle Fork South Beaver Creek have led to a reduction in the BMIBI scores. Siltation and sedimentation have caused a loss of riffle habitat, which limits the growth of benthic macroinvertebrates.

Siltation and sedimentation were determined to be a problem based on habitat data collected by the DNR/UHL biological assessment team (Table 4; Appendix I). The percent silt is much greater than the average and median for the ecoregion reference locations. The high percent embeddedness of the riffles at site 45 is also indicative of a siltation problem. Although the percent total fines is lower at site 47 than the reference condition, the accumulation of muck and detritus is quite extensive. The lack of riffle and run limits the diversity of habitats available to aquatic organisms and thereby limits the diversity of the organisms themselves. In addition, the field team noted that the standard habitat plates were heavily silted at both sites.

We are confident that the quantity and accuracy of the data are sufficient. We are convinced that the comparison to reference sites within the same ecoregion is both reasonable and justified. The evidence is strong enough to justify action to reduce siltation and sedimentation in Middle Fork South Beaver Creek. Such action will have a positive effect on the biological community of the creek.

Table 4. Comparison of siltation indicators at Middle Fork South Beaver Creek sites to reference sites for the ecoregions. Reference values are average, median.

Parameter	Site 45 (downstream)	Site 47 (upstream)	Region 47c Reference
% total fines	76	46	59, 54
% silt	57	35	15, 9
% detritus/muck	*	32	*
% embeddedness	41-60	NA	**
% riffle	5	0	8.7, 8.5
% run	11	0	60, 61
% pool	84	100	32, 25

NA – no riffles to measure embeddedness; * – not measured;
** – reference measured as a range, not a numerical value

G. Make a Decision / Recommend an Action

1. Causes are identified

Middle Fork South Beaver Creek is primarily impaired by degraded water quality and secondarily by habitat alterations. The main water quality problems are nutrient enrichment that allows excessive algal growth causing depletion of dissolved oxygen and low dissolved oxygen caused by algal growth and high BOD. Silt/sediment deposition also contributes significantly to the biological impairment.

For the purposes of TMDL development, the causes of impairment are low dissolved oxygen, excess nutrients, and siltation.

2. Recommend actions

<u>Nutrients (N and P)</u>

While agricultural and urban sources of nitrogen and phosphorus must be addressed, it is also important to consider the inputs of the City of Ackley STP into Middle Fork South Beaver Creek. The wastewater lagoon provides approximately 20% of the flow found in Middle Fork South Beaver Creek for much of the year. Because the growth of algae requires both nitrogen and phosphorus, we recommend that limits be placed on the levels of either nitrate or phosphorus. If effective, these limits will provide a limiting nutrient that will slow algae growth in Middle Fork South Beaver Creek.

<u>Dissolved Oxygen</u>

The reduction of nutrient levels should decrease the growth of aquatic plants and algae and, therefore, decrease the magnitude of dissolved oxygen fluctuations.

<u>Macrophytes and Algal Growth</u>

The reduction of either available nitrogen or phosphorus should create a system in which there is a nutrient limitation on the growth of macrophytes and algae.

Silt/Sediment

A reduction in bed/bank, sheet/rill, and gully erosion should decrease the siltation and sedimentation of the streambed.

References

IAC. 2004. Chapter 567-61: water quality standards. Iowa Administrative Code [effective date 6/16/04].

IDNR. 2004. Draft Protocol for Stressor Identification. Iowa Department of Natural Resources. September 2004.

US EPA. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency. December 2000.

Appendix I

Summary of data provided by DNR Biological Assessments.

Samples were collected at two locations along Middle Fork South Beaver Creek by members of the TMDL and Water Quality Assessment Section of the DNR. A map of these locations is available in Figure 4. The two sites were sampled in September 2001.

Biological samples of both fish and benthic macroinvertebrates were collected and analyzed. Additional parameters that were sampled are:

- Flow
- Streambank Status
- Stream Habitat
- Riparian Zone Properties
- Streambed Composition

A summary of the physical and biological parameters may be found in Table 5.

Figure 4. Locations and identification codes for biological sampling sites on Middle Fork South Beaver Creek.

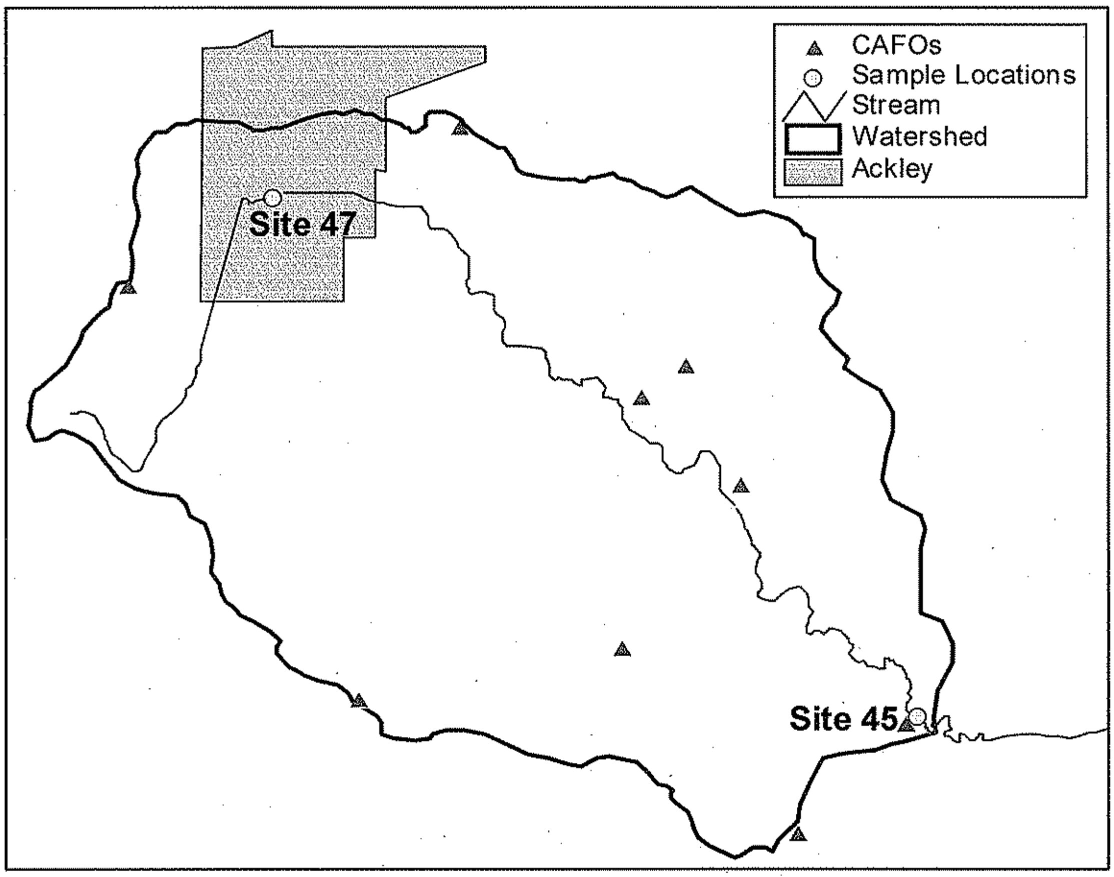


Table 5. Biological community composition at the two Middle Fork South Beaver Creek sites.

	Site 45 8/14/01	Site 47 8/14/01
Fish		
Stonecat	6	
Bigmouth Shiner	21	
Blacknose Dace	9	7
Bluntnose Minnow	46	5
Central Stoneroller	19	181
Common Carp	7	
Creek Chub	27	30
Fathead Minnow		6
Sand Shiner	5	
Spotfin Shiner	19	
Johnny Darter	13	
Golden Redhorse	34	
Shorthead Redhorse	3	
White Sucker	16	10
Bluegill	2	1
Green Sunfish	13	28
Largemouth Bass	4	
Smallmouth Bass	13	
Total Fish	258	268
Benthic Macroinvertebrates		
Basommatophora	16	54
Coleoptera	17	18
Decapoda	3	3
Diptera (Chironomidae)	257 (252)	128 (120)
Ephemeroptera	68	2
Hemiptera	21	12
Isopoda		1
Odonata	18	38
Pharyngobdellida	1	7
Plecoptera	1	
Rhynchobdellida		6
Trichoptera	56	
Tricladida	30	
Hydracarina		3
Oligochaeta	1	113
Total Invertebrates	891	385
Stream Properties		
Flow (cfs), DO (mg/l), Temp (deg. C)	1.2, 6.3, 17.1	<0.1, 7.5, 19.5
Max. Depth, Avg. Depth (ft)	3.4, 0.6	2.3, 0.3
Average Width (ft)	20	12
% Pool, Riffle, Run	84, 5, 11	100, 0, 0
% Gravel, Cobble, Boulder	18, 2, 0	8, 4, 0
% Fines (sand, silt, soil, clay)	76	46

Appendix II

Summary of data provided by University Hygienic Laboratory.

Samples were collected at two locations along the Middle Fork South Beaver Creek by the University Hygienic Laboratory (UHL) under contract with the DNR. A map of the locations is available in Figure 4.

Parameters that were sampled on a monthly basis in 2001 and 2003 are:

- Ammonia
- Nitrate/Nitrite
- Kjeldahl Nitrogen
- Orthophosphate
- Phosphorus
- Dissolved Oxygen (DO)
- Specific Conductance
- Total Suspended Solids (TSS)
- Temperature
- Flow Rate
- pH
- CBOD

All of the data for the parameters listed above are shown in Table 6.

Auto samplers were deployed at site 45 in 2003 to measure variations in DO and temperature. Graphs of these changes over time may be found in Figure 5. Data collected along with the deployment are in Table 7.

Table 6. Data collected by UHL for the DNR in 2001 and 2003.

Collection Date	NH3 as N (mg/l)	CBOD (20 day) (mg/l)	CBOD (5 day) (mg/l)	DO (mg/l)	pH	Temp (deg C)	Filterable Ortho. as P (mg/l)	Ortho. as P (mg/l)
Event Sampling - Site 45								
3/14/2001	1.6		16	11.3	7.8	0.3	0.6	
3/19/2001	0.6		2	10.4	7.5	0.7	0.4	
3/13/2003	2.8	17		11.7	8	1.4		0.77
4/8/2003 (grab)	0.63	7		14.6	8.3	5.9		0.11
11/5/2003 (grab)				12.3	7.5	3		
11/4/2003 (post-peak)	0.31	15						0.39
11/4/2003 (pre-peak)	1.1	20						0.56
Monthly Sampling - Site 45								
3/6/2001	3.1		2	10.2	8.4	0.5	0.5	
4/5/2001	0.3		< 2	10.9	7.9	7.1	0.1	
5/10/2001	< 0.1		< 2	10.4	8	13.8	< 0.02	
6/7/2001	< 0.1		< 2	9.5	8	13.7	0.03	
7/5/2001	< 0.1		< 2	10.4	8.4	19	0.09	
8/2/2001	0.1		3	7.1	8.1	27.2	0.12	
9/14/2001	0.13		2	9.6	8.2	13.6		0.12
10/8/2001	< 0.05		< 2	13.8	8.6	11.4	0.08	
11/1/2001	0.4		< 2	13.8	8.3	13	0.08	
3/19/2003	1.9	12		12.4	8.2	1.6		0.2
4/1/2003	0.16	20		16.7	8.5	13.7		0.09
5/15/2003	0.07	3		10.4	8	11.4		0.07
6/12/2003	< 0.05	29		10.1	8.1	15.3		0.04
7/16/2003	< 0.05	5		9.5	8.1	18.2		0.06
8/13/2003	< 0.05	5		11.2	8.2	21.6		0.03
9/10/2003	< 0.05	10		9.6	8.1	19.5		0.03
10/13/2003	< 0.05	8		10.3	8.3	12.1		0.05
Monthly Sampling - Site 47								
3/6/2001	4.6		5	7.6	8	2	0.3	
4/5/2001	< 0.1		< 2	11.2	7.7	6.2	< 0.1	
5/10/2001	< 0.1		< 2	11.1	7.7	12.3	0.05	
6/7/2001	< 0.1		< 2	10.3	7.7	12.8	< 0.02	
7/5/2001	< 0.1		< 2	11.4	8.1	16	0.03	
8/2/2001	0.4		6	4.3	7.6	27.6	0.1	
9/14/2001	0.1		30	2.4	7.7	14.2		< 0.01
10/8/2001	< 0.05		< 2	11	8.1	11.4	0.05	
11/1/2001	0.06		< 2	9.1	7.7	12.7	0.07	
3/19/2003	0.27	18		11.6	8	1.7		0.05
4/1/2003	< 0.05	19		13.3	8	9.3		< 0.05
5/15/2003	< 0.05	3		12.7	7.9	12.1		< 0.05
6/12/2003	< 0.05	26		11.7	7.9	14.3		< 0.02
7/16/2003	< 0.05	< 2		9.6	7.8	16.9		0.03
8/13/2003	< 0.05	7		3.8	7.8	20.7		0.14
9/10/2003	< 0.05	70		11.2	8.9	19.5		0.06
10/13/2003	< 0.05	12		1.9	7.5	11.3		0.07

Table 6 (continued).

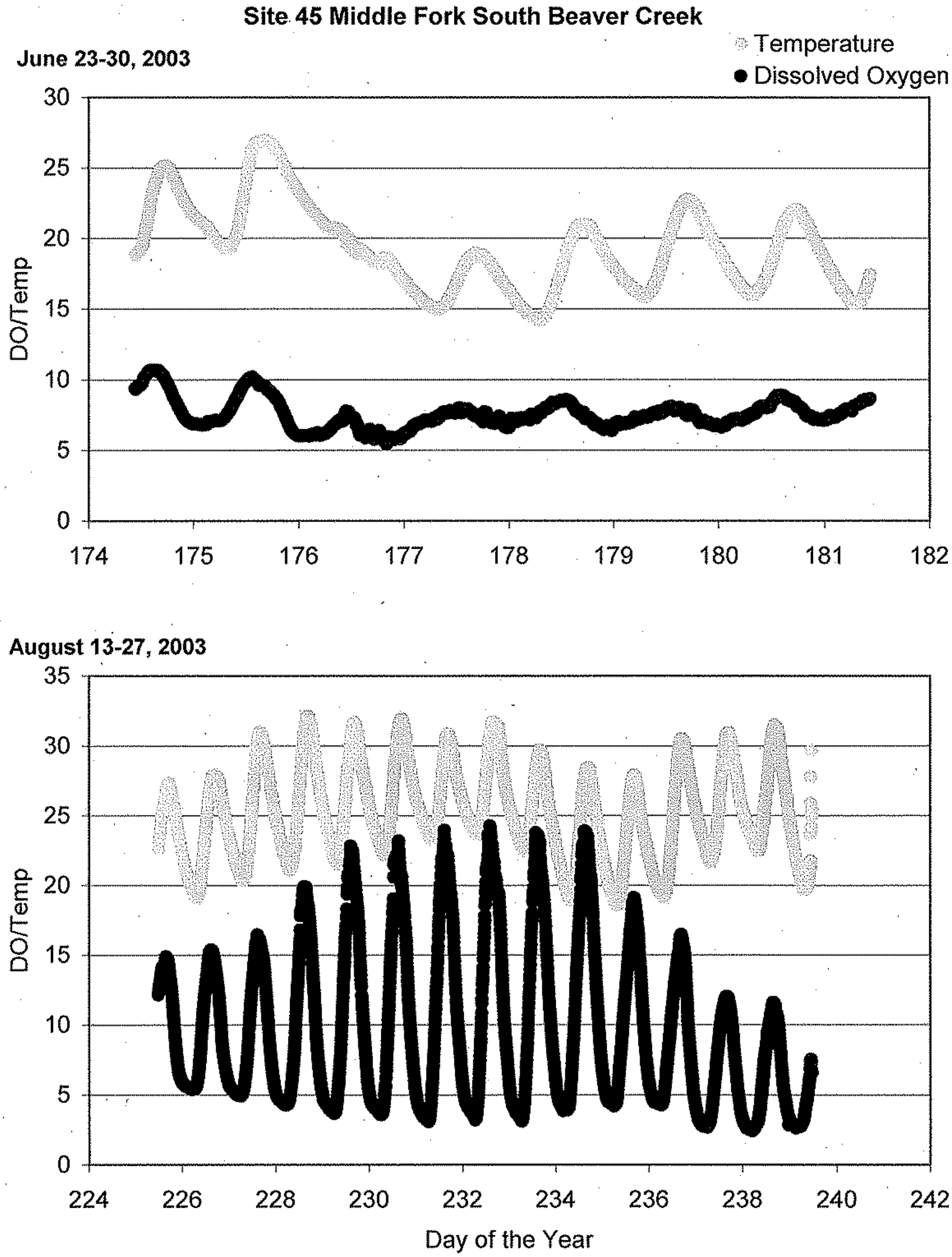
Collection Date	Flow Rate (cfs)	NO3 + NO2 as N (mg/l)	Silica as SiO2 (mg/l)	Specific Conductance (umhos/cm)	TKN as N (mg/l)	Total Phosphate as P (mg/l)	TSS (mg/l)	TVSS (mgl)
Event Sampling - Site 45								
3/14/2001	15.3	8.4		390	4.3	0.8	120	
3/19/2001	88	9.2		410	1.9	0.5	91	
3/13/2003	2.1	4.6	9.7	580	4.9	0.91	9	3
4/8/2003 (grab)	7.8	8.7		670	1.6	0.22	19	7
11/5/2003 (grab)	4.4							
11/4/2003 (post-peak)		9		440	1.5	0.49	34	7
11/4/2003 (pre-peak)		4.5		640	3.3	0.76	94	18
Monthly Sampling - Site 45								
3/6/2001	4	8.2		770	4.6	0.6	11	
4/5/2001	34.7	15		550	1.3	0.2	47	
5/10/2001	37	19		580	0.5	0.1	36	
6/7/2001	36.3	21		610	0.1	0.1	32	
7/5/2001	10	18		600	0.4	< 0.1	9	
8/2/2001	2	4.6		770	1.8	0.3	21	
9/14/2001	8	10		710	1.1	0.1	21	
10/8/2001	6	9.5		680	0.61	0.11	6	
11/1/2001	8.2	11		770	0.87	0.15	8	
3/19/2003	3.2	4.7	7.6	600	2.9	0.28	13	4
4/1/2003	1.7	9.2		680	1.1	0.25	14	4
5/15/2003	47.1	17		650	0.68	0.15	37	5
6/12/2003	30.7	19		690	0.55	0.13	35	5
7/16/2003	22.1	17		760	0.55	0.12	21	4
8/13/2003	2	4.7		570	0.91	0.08	7	2
9/10/2003	1	3.3		600	0.89	0.1	24	6
10/13/2003	0.9	6.5		820	0.74	0.11	16	4
Monthly Sampling - Site 47								
3/6/2001	< 1	7		780	5.7	0.4	< 1	
4/5/2001	5.8	15		600	0.7	0.1	11	
5/10/2001	5.3	21		690	< 0.1	< 0.1	3	
6/7/2001	5.2	23		710	0.9	0.6	9	
7/5/2001	1.4	23		690	0.5	< 0.1	8	
8/2/2001	0	1.8		430	1.8	0.2	26	
9/14/2001	1	0.9		860	2.5	0.36	28	
10/8/2001	1	12		740	0.69	0.11	42	
11/1/2001	1	9.1		1200	0.65	0.09	31	
3/19/2003	0.3	4.5	8.2	580	1.8	0.2	24	10
4/1/2003	1	9.1		790	0.58	0.12	2	< 1
5/15/2003	5	18		740	0.52	0.07	26	3
6/12/2003	3.9	19		810	0.42	0.02	2	< 1
7/16/2003	2.9	13		870	0.3	0.03	3	1
8/13/2003	1.1	< 0.1		450	1.1	0.24	23	4
9/10/2003	< 1	< 0.1		490	16	2.3	180	80
10/13/2003	0.1	< 0.1		450	2.6	0.82	67	20

Table 7. Data from samples collected during auto sampler deployments at site 45 in 2003.

Test Description	Location *	6/23/2003	6/30/2003	8/13/2003	8/13/2003 (duplicate)	8/20/2003	8/27/2003
Flow Rate (cfs)		11.2	21.3	2	2.4	1.7	1.7
TDS (mg/l)		370	410	360		330	360
TSS (mg/l)		15	52	7	28	42	39
TVSS (mg/l)		4	7	2	9	18	10
Turbidity (NTU)		6	16	5.5		17	18
DO (mg/l)		9.2	9.3	11.2	11.7	12.5	7.6
CBOD (20 day) (mg/l)		6	7	5	8	<2	35
Field pH		8	8	8.2	8.3	8.6	8.2
Field Temp. (deg. C)		19.1	18	21.6	22.3	25.6	21.2
NH3 Nitrogen as N (mg/l)		<0.05	<0.05	<0.05	0.06	<0.05	<0.05
NO3 + NO2 Nitrogen as N (mg/l)		17	18	4.7	4.7	2.5	2.9
TKN (mg/l)		0.6	0.71	0.91	2.2	2.6	1.8
Orthophosphate as P (mg/l)		0.08	0.06	0.03	0.03	<0.02	0.03
Total Phosphate as P (mg/l)		0.09	0.11	0.08	0.31	0.22	0.27
Silica as SiO2 (mg/l)		11	12	4.2		1.6	7
Spec. Cond. (umhos/cm)				570			
Chloride (mg/l)		24	25	35		39	40
Chlorophyll A (ug/cm2)	periphyton	79	40	15		16	42
Chlorophyll A (ug/cm2)	sediment	42	11	4.4		17	80
Chlorophyll A (ug/l)		15	31	37		360	91
Chlorophyll B (ug/cm2)	periphyton	17	2.3	1.1		2.4	0.6
Chlorophyll B (ug/cm2)	sediment	3.2	0.1	0.2		<0.1	0.3
Chlorophyll B (ug/l)		2	2	<1		1	<1
Chlorophyll C (ug/cm2)	periphyton	0.9	1.6	0.7		0.5	1.3
Chlorophyll C (ug/cm2)	sediment	<0.1	<0.1	<0.1		<0.1	1.2
Chlorophyll C (ug/l)		<1	<1	3		28	4
Corr. Chl. A (ug/cm2)	periphyton	71	37	13		14	32
Corr. Chl. A (ug/cm2)	sediment	26	5.9	2.1		11	50
Corr. Chl. A (ug/l)		13	24	33		320	84
Pheophytin (ug/cm2)	periphyton	11	3.7	2.7		2.2	13
Pheophytin (ug/cm2)	sediment	26	7.7	3.6		9.6	45
Pheophytin (ug/l)		3	11	4		40	7
Sample Volume (ml)	periphyton	265	226	130		80	85
Sample Volume (ml)	sediment	150	232	36		110	120
Filter Volume (ml)	periphyton	30	40	10.4		30	20
Filter Volume (ml)	sediment	15	45	10.4		10	15

*Samples were collected in the water column unless otherwise noted.

Figure 5. Dissolved oxygen and temperature measurements in Middle Fork South Beaver Creek.



Appendix III

Summary of data from the City of Ackley STP.

Samples of treated effluent are collected regularly for water quality analysis. Table 8 provides information about ammonia, CBOD5 and flow from the aerated lagoon system.

Parameters that are reported on a monthly basis are:

- Ammonia
- CBOD5
- pH
- Flow Rate
- Total Suspended Solids (TSS)

Table 8. Data from the City of Ackley wastewater treatment facility

	Ammonia (mass)	CBOD5 (mg/l)		30-day avg Flow		Maximum Flow	
	30-day avg	30-day avg	7-day	mgd	cfs	mgd	cfs
5/03	51.77	8	13	0.57	0.88	0.85	1.31
4/03	38.36	21	27	0.29	0.45	0.38	0.59
3/03	30.32	35	41	0.19	0.29	0.27	0.42
2/03	27.17	26	36	0.17	0.26	0.19	0.30
1/03	26.68	9	12	0.17	0.27	0.23	0.35
12/02	27.62	7	9	0.20	0.31	0.25	0.39
11/02	21.67	4	5	0.20	0.31	0.27	0.42
10/02	17.65	6	12	0.22	0.35	0.31	0.48
9/02	9.02	6	8	0.23	0.36	0.34	0.53
8/02	3.58	9	12	0.39	0.60	0.53	0.82
7/02	7.90	11	18	0.24	0.37	0.40	0.62
6/02	18.40	11	16	0.27	0.42	0.81	1.25
5/02	34.58	8	14	0.43	0.67	0.60	0.93
4/02	22.18	26	34	0.30	0.47	0.50	0.77
3/02	27.47	25	26	0.27	0.42	0.37	0.57
2/02	31.40	23	30	0.23	0.36	0.32	0.50
1/02	20.03	12	19	0.18	0.28	0.23	0.35
12/01	99.12	3	14	0.38	0.58	0.92	1.42
11/01	10.00	2	2	0.38	0.58	0.72	1.11
10/01	70.21	3	4	0.38	0.58	0.83	1.28
9/01	24.43	3	5	0.38	0.58	0.79	1.22
8/01	16.94	7	7	0.30	0.46	1.32	2.04
7/01	13.43	3	5	0.31	0.48	0.80	1.24
6/01	26.43	4	5	0.71	1.10	1.15	1.79
5/01	43.52	5	7	0.86	1.32	1.27	1.97
4/01	75.31	14	24	0.86	1.33	1.56	2.42

Appendix IV
Summary of data from Legacy STORET.

Samples were collected in Middle Fork South Beaver Creek on September 22, 1975 at two locations. Locations are mapped in Figure 6 and data from the samples are found in Table 9.

Figure 6. The locations of the two sampling sites used in 1975.

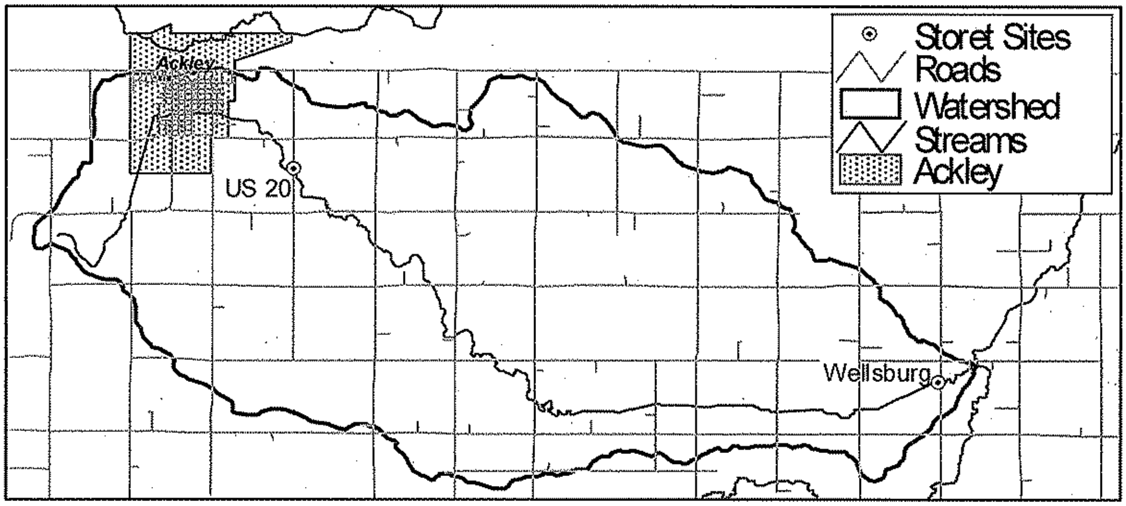


Table 9. Data collected on 9/22/1975 in Middle Fork South Beaver Creek.

PARAMETER	US20	Wellsburg
ALKALINITY, PHENOLPHTHALEIN (MG/L)	0	2
ALKALINITY, TOTAL (MG/L AS CACO3)	278	184
AMMONIA, UNIONZED (MG/L AS N)	0.00068	0.00064
BOD 5 DAY (MG/L)	7	2
CHLORIDE,TOTAL IN WATER (MG/L)	120	39
COD LOWLEVEL (MG/L)	52	22
DO (MG/L)	9.3	12.4
DO SATUR (PERCENT)	91.3	124.0
FECAL COLIFORM	69000	720
NITRATE NITROGEN, TOTAL (MG/L AS N)	1.3	2.6
NITRITE NITROGEN, TOTAL (MG/L AS N)	0.044	0.038
NITROGEN, AMMONIA, TOTAL (MG/L AS N)	0.05	0.01
NITROGEN, ORGANIC, TOTAL (MG/L AS N)	1.5	0.35
PH LAB SU	7.7	8.35
PHOSPHATE, TOTAL (MG/L AS PO4)	5.2	0.03
RESIDUE DISS-105 C (MG/L)	864	433
RESIDUE TOT NFLT (MG/L)	33	21
RESIDUE, TOTAL (MG/L)	897	454
SPECIFIC CONDUCTANCE (UMHOS/CM)	1290	622
TURBIDITY, (JACKSON CANDLE UNITS)	33	28
WATER TEMP (CENT)	15	16.5